T31

(209)

SSAB

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Bradford Residual Oil
Athabasa Ft. McMurray

Undersökning av Californisk skiffer.

Från Californien anlände i maj 1951 ett skifferprov, förpackat i två säckar.

Provet krossades till 10-20 mm kornstorlek. Vid ytterligare nedkrossning visade sig skiffern vara mera lättkrossad än svensk skiffer.

1. Analys av skiffern.

Spec.vikt. = 1 ,32

Elementaranalys: C = 23,5 %, varav 0 % karbonatkol.

H = 3,35 %

S = 2,94 %

Askhalt = 61,2 %

Värmevärde: 2760 kcal/kg.

2. Standardpyrolys.

2 kg skiffer upphettades i elektriskt uppvärmd retort till 550°C på 26 timmar. Med täta mellanrum uttogs gas- och oljeprover, vilka analyserades. Produktionen av olja, vatten och gas mättes en gång i timmen. Under försöket erhölls:

Olja: 175 ml/kg

Vatten: 5,6 ml/kg

Koks: 74,8 vikts %

Gas: 54,2 liter/kg.

Produktionen och produkternas sammansättning framgår av kurvblad 1-3.

Genomsnittssammansättning och egenskaper:

Olja: Spec.vikt 0,92

Svavel: 4,7 %

Jodtal: 113

pour point: -24°C

destillationskurva (ASTM): se diagram 4.

överdest. under 230°C = 27 volyms %.

Gas: Analys: (Gas från Fischerpyrolys)

H_2S	9,6 %
CO_2	2,8 %
CO	1,6 %
H_2	24,7 %
$C_nH_{2n+2}+N_2$	48,9 %
C_nH_{2n}	12,4 %
	100,0 %

Värmevärde: 5680 kcal/Nm^3

Koks:

C = 12,7 %

H = 1,0 %

S = 1,58 %

aska = 21,6 %

W_{kcal} = 980 kcal/kg

Vatten:

Fenolhalt: 0,018 g/l

ammoniak: 2,9 g/l.

3. Askans smältpunkt.

Askans smältpunkt överensstämmer med Kvarntorpsskifferns.

4. Kaloribalans vid pyrolys av 1 kg skiffer.

Ing. kalorier: 2760. Utg. kalorier:

olja	1590
gas	310
koks	730
	2630
diff.	130
	2760

5. Kommentar och slutsatser.

Den californiska skifferns oljehalt är nära 3 ggr så hög som Kvarntorpsskifferns. Koksens värmevärde är högt och bör räcka för pyrolysens genomförande i Kvarntorpsretorten. Någon sintring av askan har ej visat sig.

Beträffande produkterna må nämnas, att oljan har hög svavelhalt (4,7 %) och låg pour point (-24°C). Brytningsindex ligger högt (ca. 1,52), vilket tyder på hög halt aromatiska ämnen. Gasen har lägre svavelhalt än Kvarntorpsskifferns gas, men en ekonomisk utvinning av svavel torde vara möjlig. Pyrolysvattnet innehåller 2.9 g NH_3 per liter, vilket icke torde räcka till för en ekonomisk utvinning av ammoniak.

Per ton torr, pyrolyserad skiffer erhålles:

166 kg råolja

0,18 kg NH_3

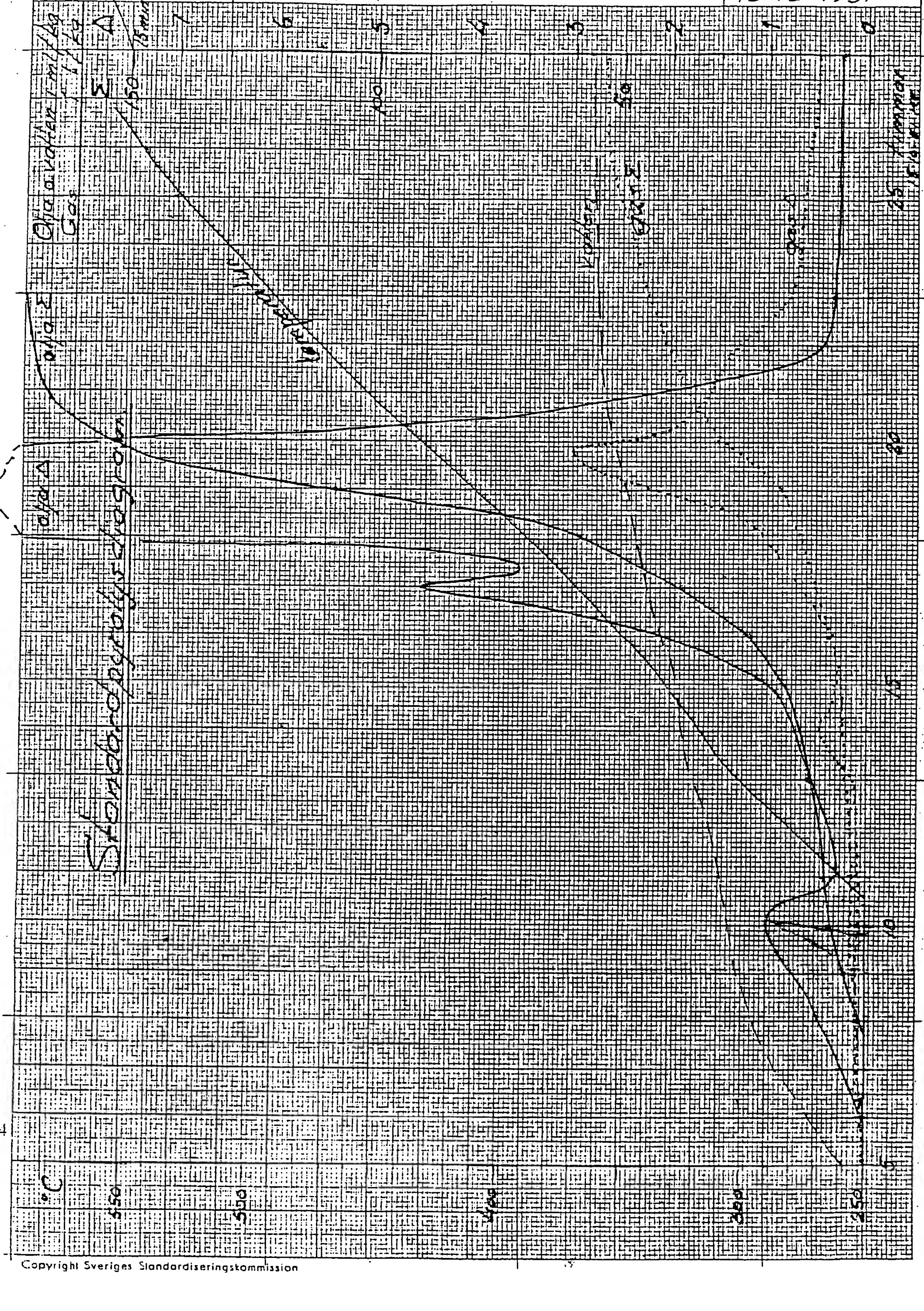
8,25 kg svavel

50,5 m^3 rengas.

Närkes Kvarntorp den 17.12.51.

G. Salomonsson

PYROLYS-LAB. | Californien | 15·12·1951



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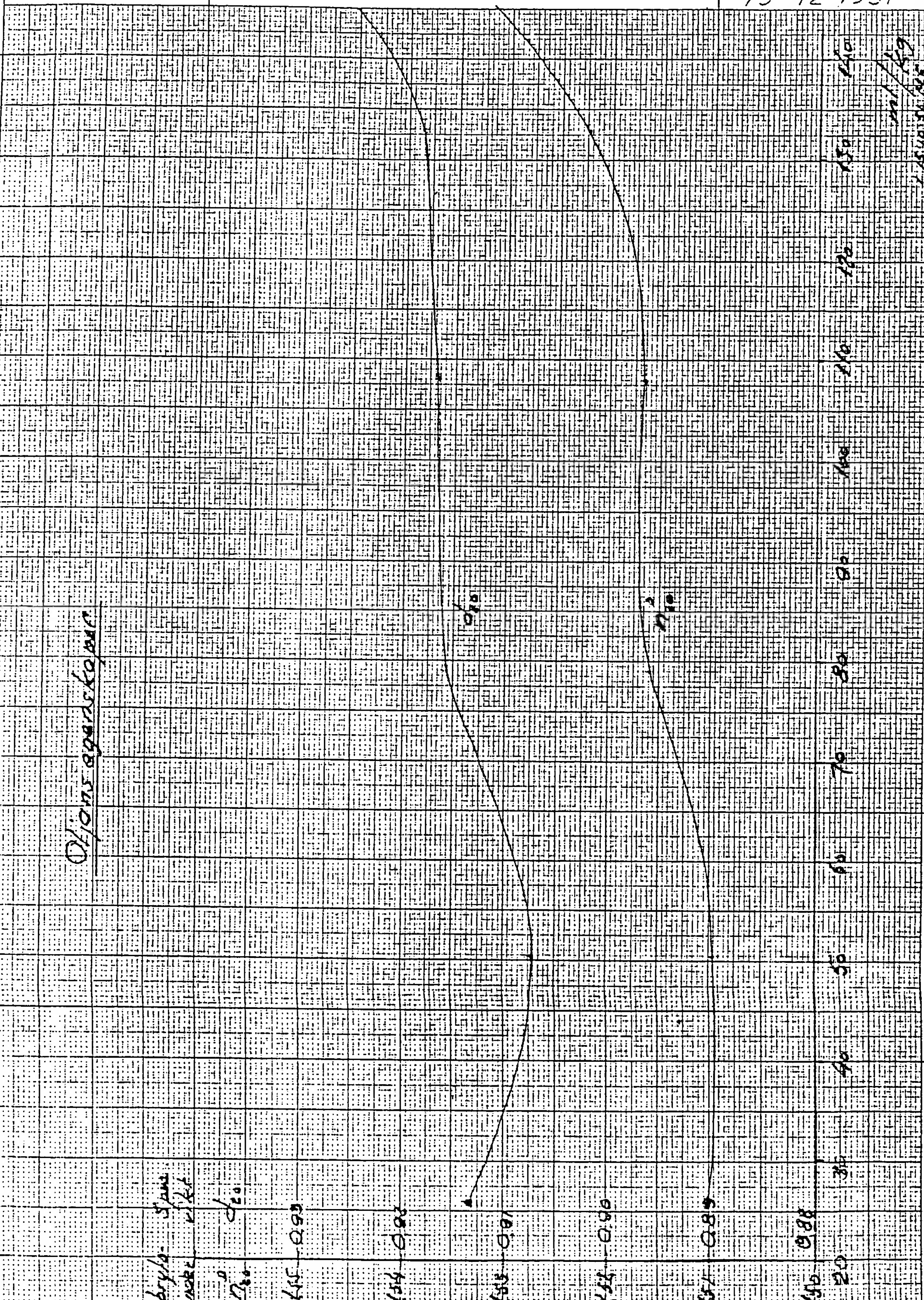
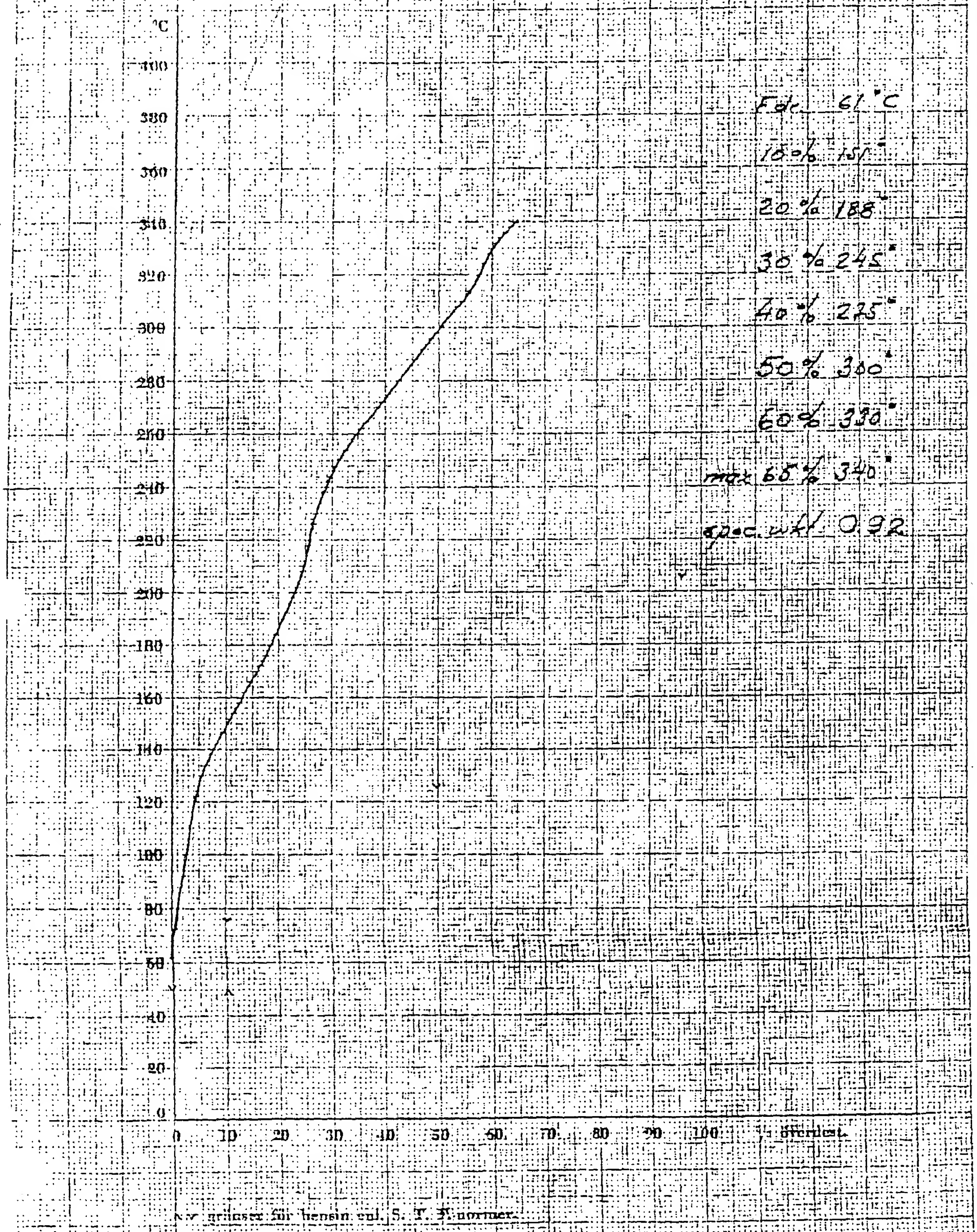
PYROLYS-LAB. | Californien | 15·12·1951



ASTM-destillationskurva för *Californisk skifferolja*

Tillhör rapport nr *105* från *Pyrolyslaboratoriet*



7.3.57
/Sal

Internt bolagsbrev

Svenska Skifferolje Aktiebolaget

Ärende: Californien-skiffer	MEDDELANDE KVARN TORP	Reg. Nr 23/1 1952
Avsändare: (avd. + namn) Ing. Salomonsson	Till (avd. + namn) Dir. Wiborgh	

Härmed översändes 2 ex. av vår rapport över undersökningarna å skiffer från Black Diamond Oil Co, Californien.
Kvarntorpsmetoden torde vara användbar som jag tidigare muntligen meddelat vid vår konferens i december.
/Sal

Ankomstdatum

Örebro den 6/9 1950.

Hans Wiborgh

Från H.C. Wiborgh

Kopia till Direktör Gejrot,
Direktör Gunnar W. Anderson.

3.811
Sd

Internt bolagsbrev

Svenska Skifferolje Aktiebolaget

Ämne: ____________

Till Professor Ed. Schjånberg,
Närkes Kvarntorp.

En av Herbert Lindens kontakter, ett amerikanskt bolag Black Diamond Oil Company, förfogar över stora skifferfyndigheter.

Bolaget ifråga har per flyg sänt oss två säckar skiffer på sammanlagt 25 kg., som de ha bett oss analysera.

Jag vore därför tacksam, om Du ville låta undersöka skiffern samt överlämna en analys till undertecknad. Säckarna sändas ut till Dig personligen genom Fröken Norders försorg.

Örebro den 6/9 1950.

Hans Wiborgh

Från H.C. Wiborgh

Kopia till Direktör Gejrot,
Direktör Gunnar W. Anderson.

1. Utländska skiffrar. /70 ∠ /05

a. Colorado-skiffer.

Från tidigare försök med Colorado-skiffer i Rockesholms-ugnen (se förra årsredogörelsen) fanns kvar ett parti på 20-25 ton. Detta parti har använts för prov i experimentugnen (5 fack). Denna drevs som ett Bergh-fack med möjligheter till återföring av okondenserbar gas till koksschaktet. Proven skulle ge upplysning om koksen gick att bränna ut och hur snabbt förbränningen kunde ske utan risk för sintring samt om möjligt vilka utbyten, som kunde erhållas. Beträffande detaljerna hänvisas till en separat rapport.

Sammanfattningsvis kan meddelas, att vid en genomsättning av upp till 200 kg skiffer/h och fack erhölls inga sintringar, men om denna ökades med 10 % inträdde allvarliga sådana. Om genomsättningen hölls så lågt som 110 kg/h (ca. 600 t per Bergh-ugn och dygn) blev värmeutvecklingen per tidsenhet för liten för att tillfredsställande pyrolys skulle erhållas. Man ligger på gränsen för värmevärdet på den koks, som vid förbränning skall ge pyrolysvärmet. Återföring av okondenserbar gas till koksbädden misslyckades troligen på grund av olämplig brännareplacering. Tillräckligt material fanns icke för ytterligare undersökningar.

På grund av materialets grovhet (13-32 mm) inträffade ideligen hängningar och tendens till bakning av skiffern i retorterna förekom. Utbränningen var bra, men oljeutbytet icke högre än ca. 60 % räknat på Fischer. Gasen hade hög halt av CO_2 (karbonat i skiffern) och låg halt av C_3- och C_4-kolväten. Dess värmevärde

beräknades dock ligga omkring 4000 kcal/m^3. Oljan hade en spec.vikt av 0,91 med 18 % bensin och med 45 % kokande under 300°. Svavelhalten var 0,8 % och kvävehalten 1,9 %.

För att kunna fastställa de lämpligaste driftbetingelserna erfordras ytterligare minst 50 ton skiffer av rätt kornklass.

Colorado-skiffer NR107.

Skiffer 16,55 % C 1,89 % H medelt. 1305 cal/g

spec. vikt = 1,63 1,54 askhalt = 67,9 % svavel 0,41 %.
CO_2/g = 895 karbonat C = 4.425 %.

Pyrolys

	Standardretorten		Fischer		Provpyrolysapp.	
Olja	10,7	%	9,7	%		%
svavel	0.74	%				
spec.vikt	0,879					
pour point	+19 °C					
jodtal.	75					
kcal/g	= 10138					
Gas	23,5	Nm^3/ton.	18.66	Nm^3/ton.		Nm^3/ton.
värmevärde	112,5	kcal/m^3		kcal/m^3		
CO_2 + H_2S	15,8	%		%		
CO.	3.2	%		%		
O_2	0,6	%		%		
C_nH_{2n}	4,4	%		%		
C_nH_{2n+2}	38.0	%				
H_2	38.0	%		%		
N_2	10.0					
H_2S		%	5,06	%		
Koks.	84,6	%	87,51	%		
C	9,37	%				
H	0,31	%				
värmevärde	102	kcal/kg				
askhalt	76,1					
svavel.	0,49	%.				
Kondensvatten.	1,94	%	1,00			
Fenol.	g/l	g/l.				
Ammoniak	10,63	g/l				

Gasanalys enl. PODBIELNIAK.

H_2S = 5,0 %
CO_2 = ~~10,8~~ 11,3 % } 16,3
C_1 = 15,9 %
C_2H_4 = 0,7 %
C_2H_6 = 4,9 %
C_3H_6 = 1,3 %
C_3H_8 = 2,0 %
iso C_4 = 0,3 %
n C_4 = 1,4 %
C_5 o. högre 0,5 % } 27,1
Σ

n - C_4 = 1,4 %
C_5 och högre = 0,5 %
inert = 56,6 %

beräknat Weff =

Gasanalys enl. ORSAT-FRIEDRICH.

H_2S = 5,0 %
CO_2 = 11,3 % } 16,3 %
CO = 3.3 %
H_2 = 39.2 %
N_2 = ~~10,1~~ 7,8 % } 50,3
C_nH_{2n} = 4,5 %
C_nH_{2n+2} = 28.9 % } 33,4
100,0

3. Fischer-pyrolys:

Olja = 9,7 vikt-%
Vatten = 1,0 vikt-%
Gas = 18,1 liter/kg
Koks = 87,5 vikt-%

Test run no. 2.

Test started: , finished: Duration of test: hours.

Retorting conditions:

Temperature A (see drawing)	900	°C	=	°F
Temperature C (- " -)	725	°C	=	°F
Temperature of recirculated flue gas	230	°C	=	°F
Steam admission	95	kg/h	=	lbs/h
Steam temperature	340	°C	=	°F
Steam pressure	1,32	atü	=	psig
Raw shale charged	–	tons/day	=	lbs/h
Fuel gas consumed	34,5	m^3/h	=	cuft/h
Fuel gas heating value (aver)	2820	$kcal/m^3$	=	BTU/cu.ft.

Condensing conditions:

Gas temperature before scrubber	93	°C	=	°F
Gas temperature after tube condenser		°C	=	°F
Crude oil produced		l/day	=	gals/day
Crude gas produced		m^3/h	=	cuft/h
Water produced		l/h	=	gals/h

Yields:

Crude oil		l/ton	=	gals/ton
Crude oil % of Fischer assay =				%
Crude gas	112	m^3/ton	=	cuft/ton

Properties of products (see also separate table):

Crude oil: spec. gravity		=	°API
Crude oil: gasoline content (< 200°C / < 400°F)			% by volume
Crude gas: heating value (gross)	$kcal/m^3$	=	BTU/cu.ft.
Retort shale: heating value (approx.)	kcal/kg	=	BTU/lbs.

Calorific balance: (basis 1 metric ton of shale)

Calories input:

Raw shale (combustion heat)	kcal/ton	=	%
Admitted steam	- " -	=	%
Fuel gas	- " -	=	%
Total	kcal/ton	=	100 %

Calories output:

Retort shale (combustion heat)	kcal/ton	=	%
Produced crude oil	- " -	=	%
Produced crude gas	- " -	=	%
Water from scrubber	- " -	=	%
Not measured and losses (by diff.)	- " -	=	%
Total	kcal/ton	=	%

Nr	Datum	% olja	% vatten	% koks	Gas Nm^3/ton	Anm
1	31.8.48	28.72	4.20	59.52	82.61	
2	3.9.48	26.97	3.8	62.2	80.43	
3	9.9.48	29.96	3.9	62.50	74.78	

Fischerdestillationer av Coloradoskiffer B

Nr	Datum	% olja	% vatten	% koks	Gas Nm^3/ton	Anm.
1	14.9	7.13	1.6	89.52	15.22	Avbrott 2 min för byte av gastub.
2	16.9	6.62	1.42	90.05	11.71	
3	18.9	7.45	1.7	89.25	13.22	

Gasanalyser enl. Orsat på gas från Coloradoskiffer A

	$CO_2 + H_2S$	C_nH_{2n}	O_2	CO
Dest. 2 ↓	8.7 %	6.3 %	12.2 %	0.6 %
Dest 3	6.4 %	5.3 %	12.6 %	0.6 %
Dubbelprov (3)	6.4 %	5.4 %	12.5 %	0.6 %

Sept. -48.

G.E.

Undersökning av Colorado-skiffern.

1. Skiffer.

Ur den stora sändningen Colorado-skiffer, 2300 säckar, vilka anlände till Kvarntorp i augusti 1951, uttogos prover ur tre säckar, placerade på olika ställen i det uppstaplade partiet. Vid Fischer-pyrolys visade sig de tre proverna ha överensstämmande egenskaper, varför den mera utförliga undersökningen inskränkte sig till ett av proverna.

Provet krossades till 10-20 mm kornstorlek. Vid ytterligare nedkrossning visade sig skiffern vara hårdare än svensk skiffer.

Spec.vikt: ca. 1,5

Elementaranalys: C = 16,55 % varav 4,48 % karbonatkol. 4.5 12.0 % org. C

H = 1,89 %

S = 0,41 %

Askhalt: 67,9 %

Värmevärde: 1305 kcal/kg. = 2350 BTU/lb

2. Standardpyrolys.

22.5 10 lbs 13 kg skiffer upphettades i elektrisk uppvärmd retort till 550°C på 1030°F 24 hours 24 timmar. Med täta mellanrum uttogos gas- och oljeprover, vilka analyserades. Produktionen av olja, vatten och gas mättes en gång i timmen. Under försöket erhölls:

Olja: 107 ml/kg = 26 gal./ton

Vatten: 1,9 vikts-% varav 0,7 % före 250°C.

retorted shale Coke Koks: 84,6 vikts-%

Gas: 23,5 liter/kg. = 760 cu ft / ton

Produktionen och produkternas sammansättning framgår av kurvblad 1-3.

Genomsnittssammansättning och egenskaper:

Olja. Spec. vikt = 0,879 (se diagram 3). gravity

sulphur svavel = 0,74 %

iodine number jodtal = 75

pour point = +19°C (mycket vax i oljan!) 66°F

destillationskurva (ASTM) se diagram 4.

överdest. under 230°C: 27 volyms-%.

Gas. Analys: H_2S = 5,0 %

CO_2 = 11,3 %

CO = 3,3 %

H_2 = 39,2 %

N_2 = 7,8 %

C_nH_{2n} = 4,5 %

C_nH_{2n+2} = 28,9 %

därav: C_1 = 22,2 %; C_2 = 5,6 %; C_3 = 3,4 %; C_4 = 1,7 %; C_5 och högre 0,5 %

Värmevärde: W_{eff} = 4290 kcal/Nm³
(ber. ur anal.) 475 BTU/cu ft

Koks.

C = 9,37 %

H = 0,31 %

S = 0,49 %

aska = 76,1 %

W_{kcal} = ~~102~~ 100 kcal/kg = 180 BTU/lb

Under pyrolysen hade koksen i viss grad bakat ihop sig, delvis till hårda, men relativt spröda klumpar.

Vatten. Fenolhalt = 0,03 g/l.

ammoniakhalt = 10,63 g/l

3. Fischerpyrolys: Olja = 9,7 vikts-%

Vatten = 1,0 vikts-%

Gas = 18,1 liter/kg.

Koks = 87,5 vikts-%.

4. Askans smältpunkt.

Askans smältpunkt ligger lägre än Kvarntorps-skifferns.

5. Kaloribalans vid pyrolys av 1 kg skiffer.

Ingående kalorier: 1305.	Utgående kalorier:	olja	1070	85 %
		koks	86	7 %
		gas	100	8 %
			1257	
		diff.	48	
			1305	

6. Kommentar och slutsatser.

Colorado-skifferns oljehalt är nära dubbelt så hög som Kvarntorps-skifferns. Koksens värmevärde är mycket lågt, och räcker ej till för pyrolysens genomförande i Kvarntorps-retorten. Även med hänsyn till koksens benägenhet att sindra ihop, ställer det sig tvivelaktigt om denna metod går att använda.

Beträffande produkterna må nämnas, att oljan har låg svavelhalt (0,74 %) och är på grund av hög vaxhalt praktiskt taget fast vid rumstemperatur. Den har ett relativt högt brytningsindex, vilket tyder (ca 5 %) på en hög halt ~~(ca. 5 %)~~ aromatiska ämnen. Gasen har lägre svavelvätehalt än Kvarntorps-skifferns gas, men en ekonomisk utvinning av svavel torde vara möjlig. Pyrolysvattnet innehåller 10,6 g NH_3 pr liter, vilket även torde vara tillräckligt för en ekonomisk utvinning av ammoniak.

Per ton pyrolyserad skiffer erhålles:

94 kg råolja

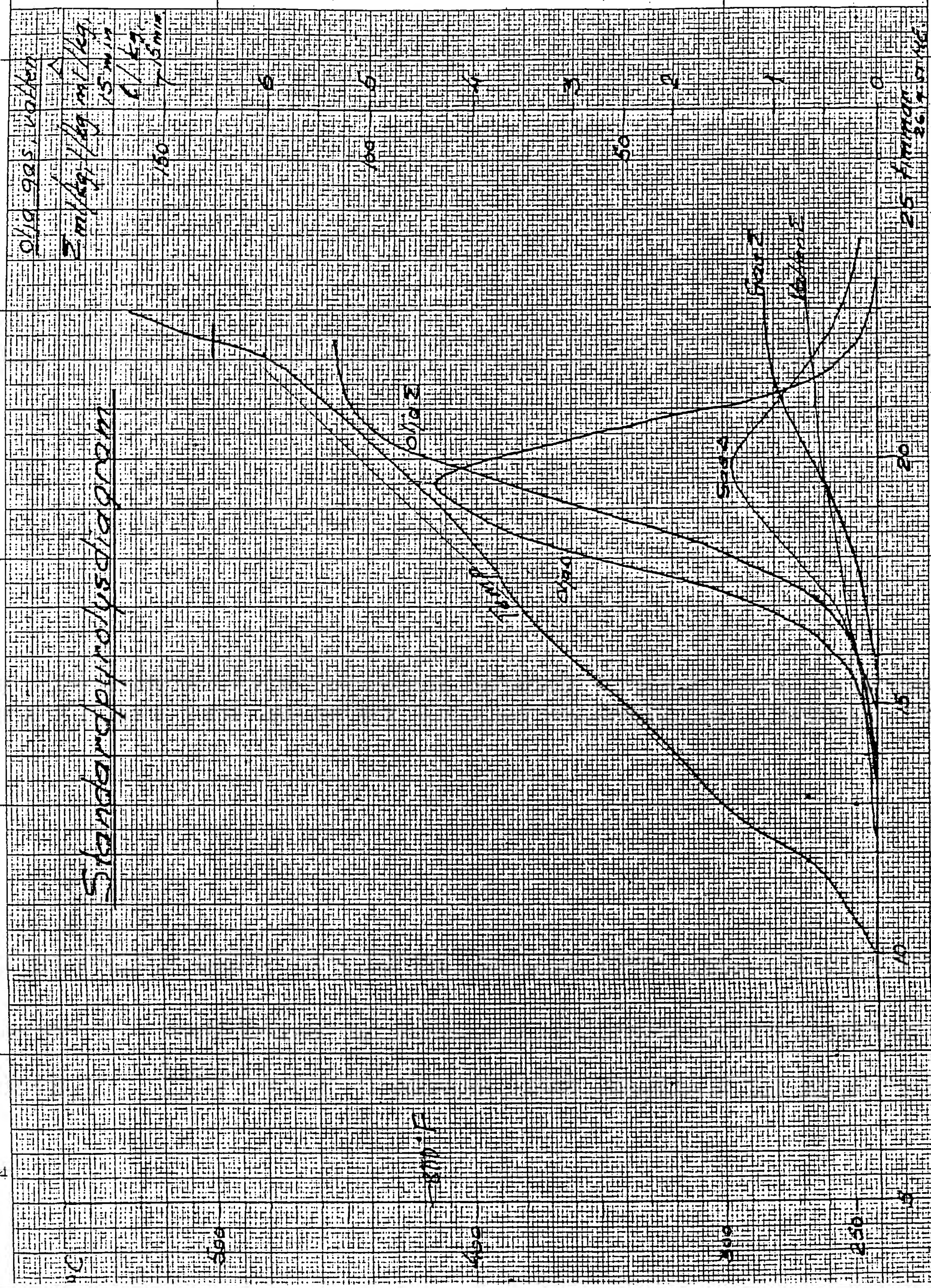
0,20 kg NH_3

1,2 kg svavel

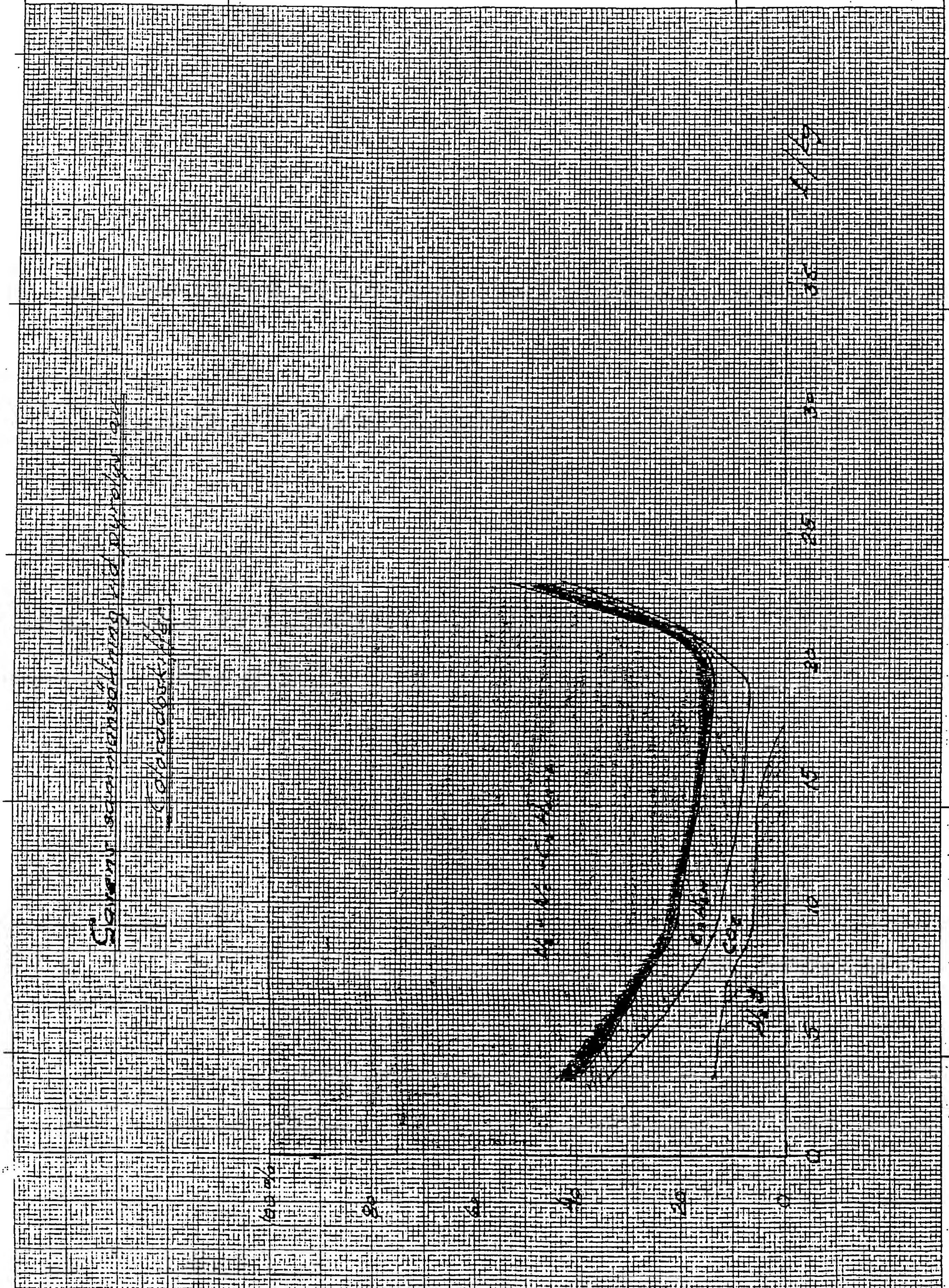
22,3 m^3 rengas.

Närkes Kvarntorp den 8.10.51.

Pyrolys-lab.	Pyrolys av Colorado-skiffer.	4.10.1951.



Pyrolys-lab.	Pyrolys av Colorado-skiffer.	4.10.1951.

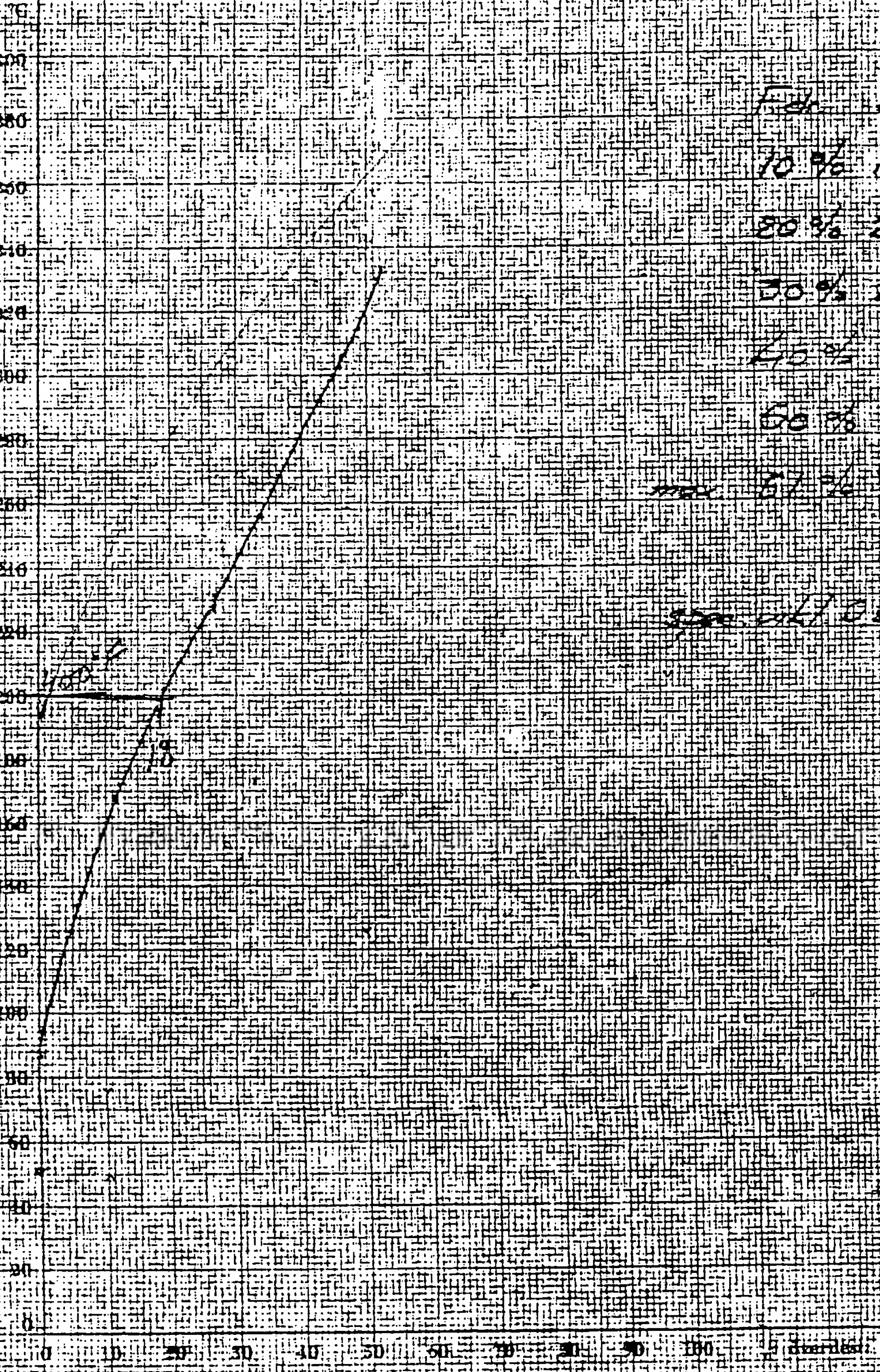


Kvarntorp

Diagram nr 4

ASTM-destillationskurva för skifferolja från ...

Tillhör rapport nr 107 från Pyrolyslaboratoriet



Fdr. 83°C

10 % 160°

20 % 204°

30 % 242°

40 % 282°

50 % 322°

max 51 % 333°

spec. vikt 0,829 20°

N. v. gränser för bensin enl. S.T.F. normer

Bl. 107 . 3000. 3. 43.

Summary of the intrareport on testing Green River oil shale from Colorado, U.S.A., in Bergh retorting process.

From the tests with Colorado oil shal in the HG retort there remained about 2o tons, which have been used in tests with the Bergh retorting process. Guiding for the decision to perform these tests was the following discussion:

When processing Swedish oil shale in Kvarntorp (Modified Bergh) units spent shale with a heating value of about 125o kcal/kg of raw shale (225o B.t.u. per pound of raw shale) is delivered to the combustion section from the retorts. This heat quantity leaves the unit as

shale ash 3oo kcal/kg of raw shale	(56o B.t.u/lb)
steam from bed coils 38o kcal/kg raw shale	(675 ")
flue gas 43o kcal/kg of raw shale	(775 ")
endotermic heat and heat losses 14o kcal/kg of raw shale	(25o ")

Assume then that Colorado oil shale is processed in a Kvarntorp unit. The shale ash leaving the combustion section is assumed to have a heating value of ~ 75 kcal/kg of raw shale (135 B.t.u./lb). The heat release during the combustion is several times less than at combustion of Swedish spent shale. The temperature in fuel bed is therefore low, which greatly affects the heat transfer (mainly radiation) to the steam producing coils. The steam generation will therefore be very low, and the presence of cooling coils only for steam generation is not justified. The flue gas volume is smaller when burning Colorado spent shale in comparison with Swedish spent shale, which means that a smaller quantity of heat, ~ 2oo kcal/kg (36o B.t.u./lb), is carried away by the flue gases. The heat duty for the Bergh process when processing Colorado shale should thus be 75 + 2oo + 14o = 415 kcal/kg of raw shale (75o B.t.u/lb), and for the Kvarntorp process a little higher.

The spent shale from a Kvarntorp retort has a little higher heating value than that from the HG retort, and Colorado spent shale from a Kvarntorp retort can be assumed to contain at least 22o kcal/kg of raw shale (4oo B.t.u./lb). Thus there is a deficiency of 195 kcal/kg (35o B.t.u/lb) in the heat duty, which can be covered by recirculation of the product gas and/or use of kerogen (incomplete pyrolysis). The product gas-calories from a Kvarntorp retort are about half the corresponding calories from a HG retort, or 18o-2oo kcal/kg of raw shale (325-36o B.t.u./lb). The Bergh or the Kvarntorp process therefore may be used for processing Colorado oil shale, if they are modified to utilization of the product gas for heating the retorts, too.

Use of cooling coils in the combustion section (Kvarntorp process) is only justified for purpose of temperature control when processing Colorado oil shale. The most interesting question to be answered is therefore:

How rapidly can Colorado spent shale be burned without cooling coils, as in the Bergh system, and without danger for caking? The tests should give an answer to this question. The yields of oil and gas that might be reached must only be a second hand-question, as the available quantity of shale was too small to determine also optimum operating data.

The test unit.

The test unit is an independently built box with 5 retorts, and belonging to this a condensing system. The box has nearly the same dimensions as an ordinary Kvarntorp-box, and is equipped with means to measure operating and production data. The product gas can be recirculated to the combustion section to be burned there. (Fig.)

The oil shale.

The Colorado oil shale has been stored outdoors in the original bags since its arrival in August 1951. At inspection the appearance of the shale was quite unaltered, and the mean Fischer assay-value was 9,6 % by weight of oil at the tests in april 1953 compared to 9,8 % at the tests in Febr. 1952.

The size of the shale, screened to minus 1 1/4" plus 1/2" at Rifle, is considered to be far from ideal. Average of the sieve analyses was:

+ 3o	-3o to +26,7	-26,7 to +22,4	-22,4 to +16	-16 to + 1o	-1o to + 6	-6 to + 4	- 4	mm square mesh
0,6	6,1	19,2	4o,2	27,o	5,6	0,6	0,8	% by weight

The shale used at Kvarntorp is screened to minus 27 plus 5 mm and shall not contain more than 3o % plus 16 mm (compared to 66 % for the Colorado shale obtained).

The tests.

A series of tests with different shale throughputs was performed. The tests were mainly performed without use of product gas as additional fuel as the location of the gas burners in the combustion section was not successful. A corresponding amount of kerogen (incomplete pyrolysis) must then be used to meet the heat duty of the process, which will decrease the theoretical oil yields about 15 %.

The tests showed that the spent shale could be burned at a rate of up to 2oo kg of raw shale/h (44o lb/h) without caking. At higher rates sintered cakes w re formed that later blocked the discharging mechanism. At rates less than 1oo kg of raw shale/h (22o lb/h) the heat release in the combustion section os too low to give good pyrolysis, which is indicated by low yields and low flue gas-temperature. The fire was sensible for disturbances of feed of spent shale. A steady descendence of shale pieces seems to be an important

a tendency of the shale to coke in the pyrolysis zone (about half way down in the retorts) was noticed. Sometimes hangings were formed, but they could be loosened with bars. However when the retorts had been emptied no trace of deposits on the retort walls was noticeable.

If Colorado shale of size, which is considered ideal, is processed, the upper limit of the throughput will probably be lowered a little.

The yields of oil were 55-65 % of the Fischer assay-value except for the extreme runs, when they did not exceed 5o %. At a gas yield of 4o Nm^3/metric ton (13oo std. cuft/ton) a product gas with a gross heating value of 4ooo kcal/Nm^3 (45o B.t.u./cu.ft) could be obtained. It contained about 2o % by vol. CO_2, less than 1 % H_2S and about 3 % C_3 +C_4-hydrocarbons.

The shale ash contained only about 3 % of the original calories of the raw shale. Its heating value was about 4o kcal/kg of raw shale (7o B.t.u./lb). The carbonates decomposed considerably during the passage of the unit. At one of the middle runs with a throughput of 15o kg of raw shale/h (27o lb/h) about 15 % of the carbonates were decomposed in the pyrolysis zone and 6o % in the combustion zone.

The oil had a spec. gravity of 0,915 and had creamy consistency at 2o°C (68°F). It distilled to 17-18 % by vol. overhead at 2oo°C (392°F) and 46 % at 3oo°C (572°F). Its sulfur-content was 0,8 % by weight and nitrogen-content 1,9 %. The analyses of an over all sample of the oil is shown in the table on next page. Compared to the oil produced of Colorado oil shale in the HG retort the oil is a little heavier.

The available quantity of 2o tons was not sufficient for determination of operating data to obtain maximum yields of oil and gas. For this purpose at least 5o tons more are required.

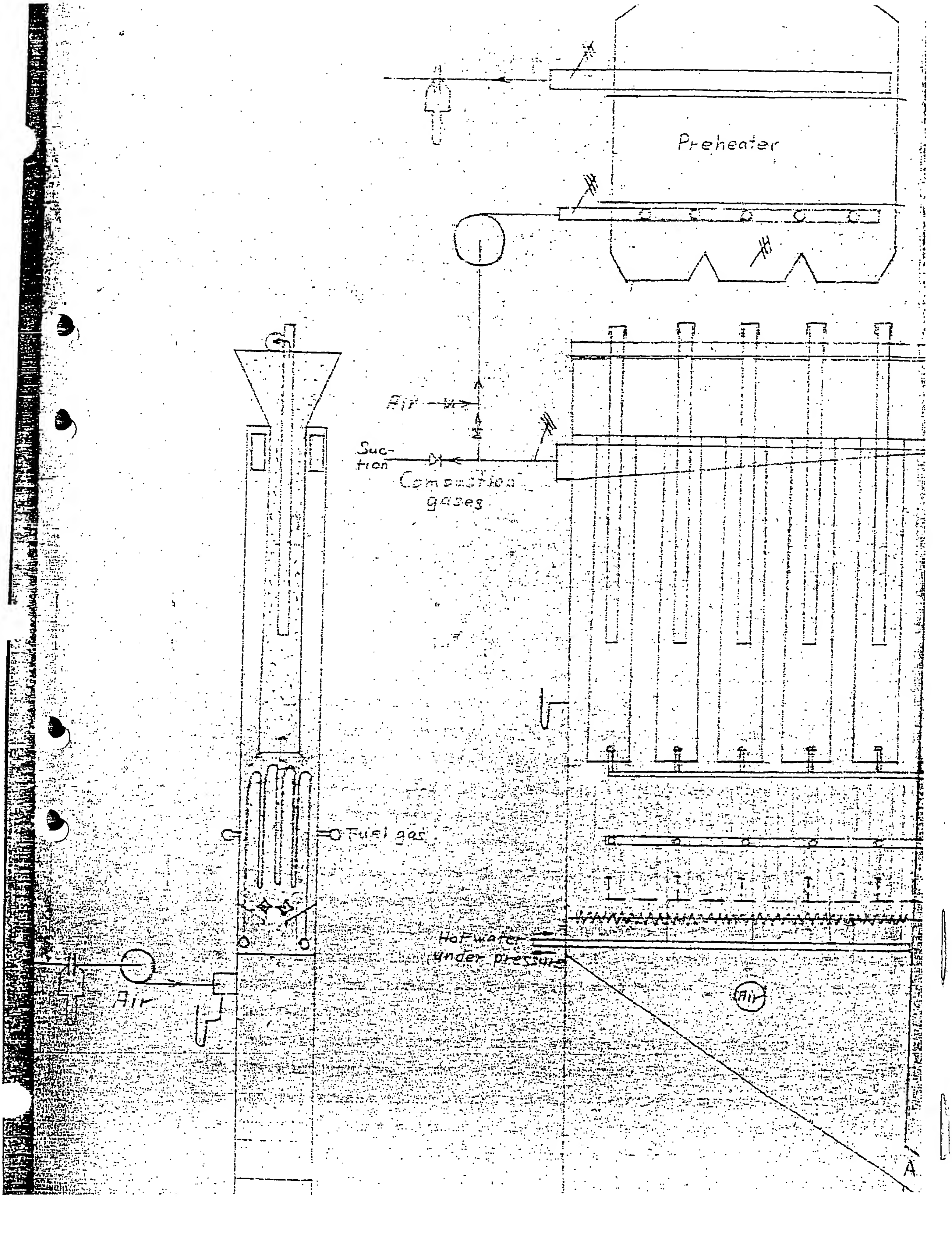
Närkes Kvarntorp in June, 1953
Svenska Skifferolje AB
Research Department

G. Schjänberg

Åke Brandberg

Analyses of over all sample of oil.

Analysis	
Sp.gr. at 2o °C	0,915
ASTM-dist. I.b.p. °C	65
5 %, °C	133
1o %, °C	165
2o %, °C	225
3o %, °C	263
4o %, °C	288
5o %, °C	307
6o %, °C	319
max., °C	319
Overdist. at 2oo °C, %	17
at 3oo °C, %	46
H_2O, %	0,6
Pour point, °C	+21
W_{gross} kcal/kg	1o17o
% C	84,o
% H	11,5o
% S	0,78
% N	1,86



Preheater
Air
Suc-
tion
Combustion
gases
Fuel gas
Hot water
under pressure
Air
Air
A

FD
8/53

Pyrolys och förbränning av Colorado-skiffer i Bergh-fack.

Från tidigare försök med Coloradoskiffer fanns ett parti på 20-25 ton kvar. Detta har använts för prov i experimentugnen, när denna var ordnad som Bergh-fack med möjligheter för återföring av okondenserbar gas till koksschaktet. Proven skulle ge upplysning om koksen från Colorado-skiffern gick att bränna, och om hur snabbt förbränningen kunde ske utan risk för sintring samt om vilka utbyten som kunde nås.

Skiffern. Skiffern, som färdigkrossad och siktad anlände till Kvarntorp i augusti 1951, hade hela tiden varit lagrad utomhus i de ursprungliga säckarna. Till utseendet var skiffern oförändrad och inga spår av vittring syntes. Vid Fischer-analys erhölls under de nu genomförda proven 9,6 vikts-% olja som medeltal mot 9,8 % vid proven i febr. 1952.

Skiffern var i jämförelse med skiffer till Kvarntorp-ugnarna grov och var enl. uppgifter från Rifle siktad med 32 och 13 mm siktdukar. På uttagna skifferprover utförda siktanalyser gav följande medeltal:

+30	- 26,7	- 22,4	- 16	- 10	- 6	- 4	-	mm kvadratiska maskor
0,6	6,1	19,2	40,2	27,0	5,6	0,6	0,8	vikts %

Över 16 mm ligger 66 % av godset mot önskvärt högst 30 % och fint gods saknas nästan helt.

Skifferns fukthalt var låg, 0,5 %.

Experimentugnen. Beträffande försöksanordningar, provtagning, etc. hänvisas till beskrivning i rapporten ang. motsvarande försök med Congo-skiffer.

Försöken. Försöken var avsedda att löpa i perioder om 2 dygn med olika genomsättning. Störningar av olika anledningar gjorde att perioderna ibland blev för korta för att möjaktigt säkra balanser och utbytesberäkningar skulle kunna göras. Störningarna bestod mest av att utmatningen av aska ej fungerade tillfredsställande. Det grova godset byggdes upp som valv ovanför valsarna p.g.a. ineffektiv vibrering, och de så uppkomna hängningarna var svåråtkomliga. Det grova godset orsakade också ideliga hängningar i retorterna, och dessutom verkade det som om skiffern under pyrolysen "bakade" (mjuknade och svällde) och orsakade hängningar längre ned i retorterna. Med spett kändes dessa ställen som segt beck. Vid tömning av retorterna syntes dock inga spår av avsättningar på retorväggarna.

Start av facket kunde ske genom vanlig teknik med vedeldning. Luftmängden för förbränningen reglerades efter rökgasernas CO_2-halt, och utsugen pyrolysgasmängd reglerades efter undertrycket i grenröret samt gasens kvävehalt. Undertrycket i rökgasschaktet hölls möjligast konstant. Medelvärden av drift- och produktionsdata för de olika perioderna framgår av tabell 1-3, och produktanalyserna återfinnas i tabell 4-9 (förutom de fullständiga Orsatanalyserna enl.

Under den första perioden (29-31/3 tabell 1) hölls en genomsättning på 95 kg/h. Härvid erhölls en relativt god fyr, men utbyten (49 % av Fischer-utbytet) och rökgastemperaturen (3oo°) visar att värmeutvecklingen per tidsenhet är i minsta laget. Försök gjordes att leda tillbaka okondenserbar gas och bränna denna i koksbädden men kort tid därefter mörknade fyrarna och pyrolysen försämrades. Dagen efter upprepades försöket med samma resultat. Om försämringen av fyrarna beror på gastillsatsen eller på annan samtidig omständighet kan ej sägas. En sådan verkan av tillsats av brännbar gas (ehuru CO_2-rik) synes märklig. Man skulle kunna tänka sig att gasen skapar en het zon längre ner i bädden dit förbränningen av koksen sedan också flyttas.

Under andra perioden (31/3-1/4, tabell 2) var genomsättningen något högre, 1o9 kg/h, dock ej så mycket som avsett. Fyrarna flammade mer än tidigare och syntes i genomsnitt vara mörkare än i början av första periden, men rökgastemperaturen var högre, upp mot 4oo°C. Olje- och gasutbytena hade också stigit det förra till 64 % av Fischervärdet.

Under båda dessa perioder erhölls endast ett koksprov med avsevärd "oljehalt", vilket kan synas märkligt med hänsyn till att pyrolysen knappast kan ha varit fullständig med så låga utbyten och ofta starkt flammande fyrar. Man får nog ej lägga för stor vikt vid koksproverna, då de äro svåra att taga ut på ett representativt sätt. Oftast får man kanske koks från retortens perifera delar och ej tvärsnittsprover.

Pyrolysgasens kvävehalt var hög, i medeltal 55-6o %. Den egentliga (rökgasfria) pyrolysgasmängden var därför bara 15-2o Nm^3/ton. Gasens CO_2-halt varierade starkt med fyrutseendet, 1o-3o % CO_2, vid nöjaktig pyrolys 2o-25 %. Drygt hälften av koldioxiden torde härstämma från karbonatsönderdelning och resten till största delen från rökgasen. Analyserna på skiffer och koks tyder på att cirka 1o % av karbonaterna sönderdelats under pyrolysen i retorterna, och askanalyserna visa att knappt hälften återfinnas osönderdelade i askan.

Luftöverskottet vid förbränningen var väl stort. CO_2-halten i rökgaserna var i medeltal 5,5 % men till dessa bidrager karbonatsönderdelningen med en dryg procent.

Askans utbränning var god. Endast 0,5-0,6% av ursprungliga 12 % organiskt kol återstod i askan.

Under tredje perioden (22/4) skulle en genomsättning på 15o kg/h hållas men störningar i utmatningen inträffade redan efter mindre än 1 dygn. En god fyr (oftm. flammande) erhölls emellertid och den visade inga sintringstendenser. Man kunde nu liksom förut lägga märke till att fyren är beroende av en jämn tillförsel av brännbart material. Skulle av någon anledning denna tillförsel mankera (störning i askutmatningen, hängningar, avknaggningar, tillförsel av för kalorifattig koks) försämrades fyren snabbt och kunde ofta inte fås normal igen utan yttre hjälp. Ang. olje- och gasutbytena kan inget bestämt sägas, då mätperioden var för kort. Uppskattningsvis erhölls cirka 8-9 l olja/h eller

mindre än tidigare och luftmängden uppgick till 1,5-2 Nm^3/kg skiffer, varvid rökgasens CO_2-halt blev omkring 9 %. Bäddtemperaturen var otvivelaktigt högre än under föregående perioder och karbonatsönderdelningen livligare.

Nästa period startades med hög genomsättning, cirka 22o kg/h. En mycket livlig förbränning erhölls som ledde till svårartade sintringar efter 12 h drift och efter 1 dygn måste ugnen släckas på grund av hinder för askutmatningen. Luftmängden var ~1,9 Nm^3 luft/kg skiffer varvid CO_2-halten i rökgasen på 1o-12 % erhölls. Karbonatsönderlningen var livlig; askanalysen visar att högst 15 % av karbonaterna finnas osönderdelade i askan. Även i retorterna var karbonatsönderdelningen kraftig, 4o % sönderdelas i dessa. Ej heller under denna period kan säkra uppgifter om olje- och gasutbyte lämnas. Oljeutbytet torde dock ej ha överstigit 5o % av Fischerutbytet. Vid gasuttag på ~ 5o Nm^3/ton erhölls, när pyrolysen gick som bäst, gas av god kvalitet och högt värmevärde, ~4500 kcal/Nm^3 (Tabell 8 analyserna 24/4 kl. 09,4o-14.1o).

Den sista perioden var avsedd att ha en genomsättning på 175 kg skiffer/h. Den oberäkneliga askutmatningen gav först en genomsättning på 2oo kg/h under 15 h (approx. 55 % oljeutbyte och 55 m^3 gas/ton av god kvalitet, tabell 8 analyserna 26/4 03 och 09,45), varefter utmatningen krånglade (dock ej p.g.a. sinter) och gav till slut en period på 1 dygn med en genomsättning av 15o kg/h. Efter störningarna i utmatningen, då genomsättningen periodvis varit mycket låg, måste fyren på nytt startas genom vedeldning. För den avslutade perioden om 1 dygn kan en approximativ balans uppställas enl. tabell 3. Oljeutbytet var 61 % av Fischerutbytet. Koksanalyserna indikera ofullständig pyrolys. Askans utbränning var god, och ~75 % av karbonaterna hade sönderdelats (~ 15 % i retorterna).

Oljeutbytena har beräknats på medelvärdena av Fischer-analyserna under försöken, nämligen 1o,2 % för försöken i slutet av mars och 9,o % i slutet av april. Variationerna i analyserna är avsevärda, vilket ansetts bero på heterogena prov. Alla ovan angivna utbyten inkluderar ej gasbensinen. Medräknas denna ökas procentuella utbytet med ~ 2 %.

Oljeanalyserna (tabell 7) är högst varierande, vilket förklaras av att proverna, som samlats dygnsvis, ej alltid håller tung- och lättolja i bildade proportioner p.g.a. den intermittenta tömningen av oljan ur de stora mättankarna för lättoljan + vattnet. Ett generalprov av all bildad olja har därför tagits och analyserats (tabell 7).

Sammanfattning.

Den vid försöken använda skiffern var olämplig vad beträffar korngraderingen (sållad med 13 och 32 mm:s såll). Denna skiffer kunde pyrolyseras och förbrännas i Bergh-fack med en hastighet av 2oo kg/h utan allvarligare sintringar. Vid genomsättning av 22o kg/h erhölls kraftiga sintringar. Med genomsättningar under ~11o kg/h blev å andra sidan värmeutvecklingen per tidsenhet för liten för att erhålla tillfredsställande pyrolys. Fyren syntes vara mycket känslig för störningar. En jämn tillförsel av brännbart material

är ett ofrånkomligt villkor och det är tydligt att man här ligger på [illegible] gränsen för värmevärdet på den koks, som skall brännas för att ge pyrolysvärme. Försök med återföring av okondenserbar gas till koksbädden gav ej goda resultat, förmodligen p.g.a. olämplig brännarplacering i bädden. Ett stöd för fyren genom gaseldning vore mycket önskvärt för att göra den mindre känslig. Gaskalorierna utgör 1/3 till 1/2 av kokskalorierna.

I retorterna orsakade det grova materialet ideliga hängningar, och skiffern visade tendens till att baka och därigenom hänga sig längre ned i retorterna.

Askans utbränning var mycket god. Dess värmevärde var ~50 kcal/kg, vilket motsvarar mindre än 3 % av skifferns kalorier. Minst hälften av karbonaterna i skiffern sönderdelas vid passagen genom facket, vilket är en svår belastning.

Utbytena av olja låg vid 55-65 % av Fischervärdet (inkl. gasbensin) utom vid högsta och lägsta genomsättningen då det ej översteg 50 %. Vid ett gasuttag på 40 m^3/ton bör ett värmevärde på 4000 kcal/m^3 erhållas. Gasen kommer att hålla ~20 % CO_2 och föga C_3-C_4-kolväten.

Oljan hade en spec.vikt av 0,915 och var vid rumstemperatur ej flytande. Den destillerar till 17-18 % under 200°C, till cirka 46 % under 300°C och 60 % kunde destilleras över innan sönderdelning började. Dess svavelhalt är ~ 0,8 % och kvävehalt 1,9%. Jämfört med den Colorado-olja, som framställdes i HG-retort, är den något tyngre (0,02 högre spec.vikt), har större del högkokande beståndsdelar och högre stelningspunkt.

Närkes Kvarntorp i maj 1953.

FD/ABg

Table 1.

Material and heat balances for Bergh retorting system on basis of 1 metric ton raw shale.

Test run with Colorado-shale (29.3.07-31.1. 14 1953) Throughput 95 kg/h.

Material	Temperature °C	Spec. heat mean value	Gross heat value	Quantity Kg	Quantity Nm^3	Heat, Mcal Sensible	Heat, Mcal Latent	Heat, Mcal Total
In Raw shale (0,5 % moisture)	5	-	141o	1ooo	-	-	141o	141o
Steam, 2,5 ata	15o	-	-	21o	-	14o	-	14o
Air	5	-	-		265o	-	-	-
Total								155o
Out Ash	5o	$0,3^x$	25^x	77o	-	1o	2o	3o
Oil	4o	$0,5^x$	$1o15o^x$	5o	-	-	51o	51o
Water	4o	1^x	-	85	-	-	-	-
Pyrolysis gas	25	-	$(23oo)^{xx}$	-	63	-	145	145
Flue gas	3oo	$0,32^{xx}$	75^{xx}	-	265o	255	2oo	455
Carbonate decomposition	-	-	-	-	-	-	-	75
Calorific losses	-	-	-	-	-	-	-	335
Total								155o

x per Kg

xx per Nm^3

Table 2.

Material and heat balances for Bergh retorting system on basis of 1 metric ton raw shale.

Test run with Colorado-shale (31/3 23-1/4 23 1953) Throughput 1o9 kg/h

Material	Temperature °C	Spec. heat mean value	Gross heat value	Quantity kg	Quantity Nm^3	Heat Mcal Sensible	Heat Mcal Latent	Heat Mcal Total
In								
Raw shale (0,7 % moisture)	5	-	141o	1ooo	-	-	141o	141o
Steam, 2,5 ata	15o	-	-	25o	-	165	-	165
Air	5	-	-	-	24oo	-	-	-
Total								1575
Out								
Ash	5o	$0,3^{x}$	25^{x}	77o	-	1o	2o	3o
Oil	45	$0,5^{x}$	$1o15o^{x}$	65	-	-	66o	66o
Water	45	1^{x}	-	75	-	-	-	-
Pyrolysis gas	25	-	$(22oo)^{xx}$	-	8o	-	175	175
Flue gas	(4oo)	$0,32^{xx}$	$5o^{xx}$	-	24oo	3o5	12o	525
Carbonate-decomposition	-	-	-	-	-	-	-	75
Calorific losses	-	-	-	-	-	-	-	21o
Total								1575

x per kg

xx per Nm^3

Table 3.

Material and heat balances for Bergh retorting system on basis of 1 metric ton raw shale.

Test run with Calorado-shale (27/4 15-28/4 06 1953) Throughput 15o kg/h

Material	Tempera-ture ^oC	Spec. heat mean value	Gross heat value	Quantity kg	Quantity Nm^3	Heat, Mcal Sensible	Heat, Mcal Latent	Heat, Mcal Total
In								
Raw shale(0,4 % moisture)	5	-	133o	1ooo	-	-	-	133o
Steam, 2,5 ata	15o	-	-	2o5	-	135	-	135
Air	5	-	-	-	19oo	-	-	-
Total								1465
Out								
Ash	5o	$0,3^x$	$6o^x$	74o	-	1o	45	55
Oil	45	$0,5^x$	$1oooo^x$	55	-	-	55o	55o
Water	45	1^x	-	54	-	-	-	-
Pyrolysis gas	25	-	$(25oo)^{xx}$	-	63	-	155	155
Flue gas	(4oo)	$0,32^{xx}$	45^{xx}	-	19oo	24o	85	325
Carbonate-decomposition	-	-	-	-	-	-	-	11o
Calorofic losses	-	-	-	-	-	-	-	27o
Total								1465

x per Kg

xx per Nm3

Table 4.

Analysis of raw shale.

Date	28/3	29/3	30/3	31/3	1/4	21/4	22/4	24/4	26/4	27/4
Fischer assay:										
oil, % by weight	10,1	10,5	10,4	10,4	9,4	9,8	8,6	9,1	7,9	9,8
coke, - " -	85,8	84,8	84,8	86,0	87,0	86,9	86,5	87,2	89,7	86,3
H_2O, - " -	1,5	1,4	1,8	1,3	1,4	1,3	2,5	1,5	1,5	1,7
Moisture - " -	0,5	0,5	0,4	0,7	0,8	0,4	0,5	0,4	0,3	0,4
Ignition loss,% by weight of dry sample	-	32,2	31,3	34,3	31,2	27,8	29,9	31,3	31,0	30,4
total C,% by weight of dry sample	17,76	18,61	15,48	19,13	16,93	16,63	17,08	16,12	15,28	15,52
carbonate C, - " -	4,66	4,79	4,92	5,08	5,02	4,92	4,78	4,63	4,92	4,65
H, - " -	2,11	1,88	1,79	2,26	2,07	1,92	2,05	1,87	1,71	1,75
W_{gross},kcal/kg dry sample	1490	1395	1235	1605	1340	1320	1415	1340	1260	1305

Table 5.

Analysis of shale coke.

Date	29/3	30/3	31/3	1/4	21/4	22/4	24/4	26/4	27/4
Fischer assay:									
oil, % by weight	0,1	0,2	2,3	0,1	1,4	0,3	0,1	0,2	0,2
coke, % - " -	99,0	98,6	95,8	99,0	93,6	95,9	94,3	95,0	95,9
H_2O, % - " -	0,6	0,5	1,5	0,6	0,2	0,1	0,4	1,2	0,8
Moisture - " -	0,2	0,2	0,2	0,2	4,3	3,6	4,6	3,5	0,4
Ignition loss, % by weight of dry sample	23,0	23,4	21,9	22,7	14,6	23,0	15,4	22,1	20,6
total C, % by weight of dry sample	8,56	8,86	8,36	8,13	10,40	8,44	6,71	7,44	8,55
carbonate C - " -	5,28	5,38	4,50	5,29	4,27	4,66	3,37	4,59	4,37
H - " -	0,59	0,58	0,74	0,56	0,75	0,72	0,61	0,66	0,70
W_{gross} kcal/kg dry sample	260	280	215	225	570	345	315	270	410

Table 6.

Analysis of shale ash.

Date	29/3	30/3	31/3	1/4	21/4	22/4	24/4	26/4	27/4
Ignition loss, % by weight	6,5	14,2	12,0	14,8	11,0	4,3	3,6	5,4	5,6
total C, % by weight	2,06	4,54	3,99	4,59	3,56	1,39	1,47	1,79	1,86
carbonate C, - " -	1,71	3,67	3,38	3,62	2,52	1,12	0,88	1,46	1,55
H, - " -	0,31	0,46	0,42	0,39	0,51	0,33	0,32	0,33	0,37
W_{gross} kcal/kg	15	35	0	55	90	20	85	55	60

Table 7.

Analysis of shale oil.

Date	30/3	31/3	1/4	23/4	24/4	26/4	27/4	Over all sample	
Sp.gr. at 20 °C	0,922	0,902	0,886	0,948	0,942	0,912	0,923	0,915	
ASTM-dist. I.b.p. °C	57	73		74		58		57 x	65 xx
5 %, °C	201	90		211		99		127	133
10 %, °C	252	141		244		151		159	165
20 %, °C	-	201		-		183		208	225
30 %, °C	-	233		-		219		240	263
40 %, °C	-	263		-		254		-	288
50 %, °C	-	-		-		269		-	307
60 %, °C	-	-		-		-		-	319
max, °C	-	-		-		-		-	319
Overdist. at 200 °C, %	5	20		4		25		18	17
at 300 °C, %	-	-		-		-		-	46
H_2O, %	0,4	1,4	8,2	0,4	3,7	1,1	3,4	0,6	
Pour point, °C	+24	+24	+21	+24	+21	+15	+24	+21	
W_{gross} kcal/kg	10160				9810			10170	
% C,	84,0				82,1			83,98	
% H	14,12				11,05			11,50	
% S	0,85				1,00			0,78	
% N,	-				-			1,86	

x on electrically heated air-bath

xx gas heated.

Table 8.

Analysis of pyrolysis gas.

te	29/3		30/3				31/3					1/4				22/4			
me	13.00	17.00	10.00	11.15	14.30	20.50	08.10	11.30	15.30	18.05	21.30	08.00	11.15	16.40	21.15	10.15	13.35	16.40	20.
ross, kcal/Nm^3	2460	x	2540	x	x		2840	x	5960	x	x	x	3270	2150	x	2460	5760	1760	›
et, "	2330	x	2330	x	x		2600	x	5550	x	x	x	3100	2010	x	2270	5340	1600	›
S, % by vol.	0,9	0,8	0,7	0,4	0,1	1,1	0,8	0,0	1,7	0,1	0,4	0,5	0,8	1,1	0,6	0,6	1,3	1,1	0,
2 - " -	26,7	25,2	23,7	20,4	12,7	20,7	22,8	10,8	24,3	16,0	18,2	14,9	17,6	24,9	15,0	17,2	29,0	32,1	15,
H_{2n} - " -	2,6	1,6	2,6	2,0	1,0	6,2	2,6	0,8	6,6	0,9	2,3	1,4	2,2	2,4	2,2	2,8	9,5	2,8	2,
- " -	0,2	1,0	0,1	0,4	1,0	1,0	0,4	2,8	0,3	4,8	0,3	0,4	0,4	0,4	0,3	6,8	1,0	0,4	0,
- " -	2,2	2,2	1,9	1,8	2,6	4,6	2,4	2,0	3,3	1,3	2,2	1,8	2,4	2,0	2,2	2,6	2,8	2,6	2,
- " -	13,0	6,6	11,2	9,8	3,2	14,6	9,6	2,4	19,5	3,9	8,0	4,0	8,6	8,2	5,1	7,0	27,6	11,4	6,
- " -	47,8	59,0	53,2	61,0	75,8	35,1	54,9	77,3	29,6	70,8	63,0	73,4	58,5	55,2	71,0	55,3	10,5	42,6	69,
H_{2n+2} - " -	6,6	3,6	6,6	4,2	3,6	16,7	6,5	3,9	14,7	2,2	5,6	3,6	9,5	5,8	3,6	7,7	18,3	7,0	2,
4 - " -				5,5															
H_4 - " -				0,4															
H_6 - " -				1,4															
H_6 - " -				0,7															
H_8 - " -				0,6															
C_4H_{10} - " -				0,2															
ner C_4 " -				0,6															
- " -				0,8															

x the gas not combustible in Junker-calorimeter.

Table 8. (cont'd)

Analysis of pyrolysis gas.

Date	24/4						26/4			27/4							
Time	09.40	11.30	13.20	14.10	16.40	20.15	09.00	09.45	15.30	01	04	8.15	11.20	13.20	15.25	20.05	2.0[illegible]
W_{gross}, kcal/Nm^3	4470		4960		2490	x		4670	x			x	2720		4150		
W_{nat}, "	4050		4620		2340	x		4390	x			x	2530		3840		
H_2S, % by vol.		0,8		0,5	0,7	0,3		0,6				0,4		0,7	0,8		
CO_2, "		29,0		28,3	25,9	18,8	26,0	26,6	12,0	12,4	14,9	15,6		20,3	29,8	22,2	17,[illegible]
C_nH_{2n} "		8,3		7,2	4,1	2,3	7,6	5,2	1,2	2,0	2,4	1,7		1,8	5,1	2,1	2,9
O_2 "		1,1		0,0	0,8	0,8	1,4	2,4	2,8	3,6	2,0	2,9		0,2	0,7	1,2	1,9
CO "		15,0		9,0	2,6	2,3	10,6	3,2	2,0	2,0	1,5	0,6		0,9	4,2	2,5	2,6
H_2 "		22,8		18,8	13,6	10,6	16,4	12,8	3,2	5,0	8,8	2,6		7,5	14,0	8,8	8,4
N_2 "		7,0		23,9	44,9	61,6	23,9	41,0	74,5	67,7	61,6	72,1		61,7	36,5	57,5	61,0
C_nH_{2n+2} "		15,8		12,3	7,4	3,9	14,1	8,2	4,3	7,3	8,8	4,1		6,9	8,9	5,7	6,2
CH_4 "		10,4												4,7			
C_2H_4 "		2,8												0,6			
C_2H_6		2,6												1,2			
C_3H_6		2,1												0,6			
C_3H_8		0,8												0,6			
i-C_4H_{10}		1,1												0,3			
other C_4		0,6												0,4			
C_{5+}		1,3												0,9			

x: the gas not combustible in Junker-calorimeter.

Table 9.

Analysis of flue gas.

Date		29/3	30/3		31/3		1/4		22/4		24/4		26/4		27/4
Time		13^{00}	10^{30}	20^{40}	08^{20}	18^{30}	13^{15}	16^{30}	10^{30}	16^{20}	10^{00}	16^{30}	14^{15}	16^{10}	11^{05}
$CO_2 + SO_2$	% by vol	6,0	4,2	8,0	2,6	2,8	3,8	4,6	8,8	5,6	12,6	7,0	3,4	4,2	3,9
C_nH_{2n}	"	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
O_2	"	14,2	15,8	9,4	17,4	17,4	16,0	15,1	11,8	15,4	9,8	13,4	16,6	16,6	16,1
CO	"	0,2	0,2	0,6	0,0	0,0	0,1	0,0	0,2	0,2	0,0	0,1	0,6	0,2	0,0
H_2	"	0,4	0,4	0,4	0,2	0,6	0,4	0,3	0,4	1,0	0,2	0,8	0,6	1,2	0,2
C_nH_{2n+2}	"	0,6	0,8	0,2	0,2	0,4	0,3	0,2	0,0	0,4	0,0	0,4	0,0	0,2	0,4
N_2	"	78,6	78,6	81,4	79,6	78,8	79,4	79,8	78,8	77,4	78,0	78,3	78,8	77,6	79,4

TESTING OF COLORADO (GREEN RIVER) OIL SHALE AT KVARNTORP, SWEDEN.

I. Mining, crushing and sampling report from Rifle (Copy).

II. Report on the testing of Colorado (Green River) Oil shale in the HG-retort at Kvarntorp, Sweden.

Colorado Oil Shale Shipped to Sweden.

Sampling throughout the crushing operation was extensive as it was thought that a complete and reliable analysis of shale would be important in a case such as this. A total of 58 samples was taken - 12 of the minus 1 1/4" plus $\frac{1}{2}$" as crushed into the storage bins; 12 of the minus $\frac{1}{2}$" fines as produced while crushing the 180 tons of product; and 34 truck load samples of the minus 1 1/4" plus $\frac{1}{2}$" taken as the shale was blended simultaneously from the three storage bins for haulage to the stockpile area.

Average Fischer assay values for the samples taken are as follow:

1. Minus 1 1/4" plus $\frac{1}{2}$" as crushed into the 3 storage bins	26.67 gal/ton
2. Minus 1 1/4" plus $\frac{1}{2}$" as blended from the bins into the 34 truck loads	26.69 gal/ton
3. Minus 1 $\frac{1}{2}$" plus $\frac{1}{2}$" as a composited sample of the 34 truck loads	26.74 gal/ton
4. Minus $\frac{1}{2}$" fines to waste while producing the minus 1 1/4" plus $\frac{1}{2}$"	24.99 gal/ton

1) Mining.

At the request of the Processing Section the Oil Shale Mine Branch blasted nine diamond drill holes through the 70 foot Mahogany ledge in the vicinity of 637 raise. The holes were detonated in two separate blasts. Shale hauled to the crushers from the first blast amounted to roughly 300 tons and shale hauled from the second blast amounted to about 200 tons. The first 78 tons of the first blast was prepared by the crushing plant for use in pilot plant operations. The remaining 222 tons of the first blast was crushed and stockpiled for shipment to Sweden. The first 55 tons hauled from the second blast was also crushed and added to the Swedish stockpile. The remaining tonnage from the second blast (145 tons) was prepared by the crushing plant for pilot plant operations.

The average grade of the 70 foot section in the vicinity where this work was conducted is 27 gallons per ton. This value was established by means of assays on a diamond drill core taken at the time 637 raise was being driven. Assays of this core are tabulated in the Oil Shale Data Book.

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1) This section of the memo was prepared by Homer Ballinger of the Mining Section.

Crushing and sampling.

All three chrushers were used to prepare the shale. The primary jaw crusher was set at 3 7/8 open, 3 1/8 closed; the secondary hammermill at a rotor speed of 425 r.p.m., 5" spacer bars, and the breaker plate at its maximum distance from the hammers; the tertiary gyratory was set at 1 1/4" on the closed side.

Both double deck vibrating sgreens were used with the 1 1/4" cloths on the top decks and the $\frac{1}{2}$" cloths on the bottom decks. The material flow was as follows: from the primary crusher to the primary vibrating screen – the oversize going to the hammermill for secondary reduction, the product made in the primary chusher going to the bins, and the fines going to waste. The discharge of the hammermill went to the secondary vibrating screen– the over-size going to the gyratory for third stage reduction and closed cycle back to this same screen. The product and fines from this secondary vibrating screen joined the corresponding streams from the primary screen.

Both product and fines were sampled – the fines by the automatic sampler on conveyor No. 9 and the product by use of a flop gate operated manually at the head end of conveyor No. 2 while entering the bins, and by a flop gate operated manually at the head end of conveyor No. 13 while blending the shale from the bins into the trucks.

The shale was crushed alternately into the 3 bins, 15 tons at a time until each bin contained 60 tons. After this, it was blended simultaneously from each of the bins to trucks for haulage to the stockpile area. Samples were taken of each 15 tons into the bins, of the fines produced for each 15 tons, and of each truck load as it was loaded by simultaneous blendning from the bins. Sampling was thus to obtain as good an analytical cross-section of the material as possible. The following is a diagram of this procedure:

Bin # 1	Bin # 2	Bin # 3
A = a	B = b	C = c
D = d	E = e	F = f
G = g	H = h	I = i
J = j	K = k	L = l

Truck loading (34 truck loads)

each truck loaded simul-taneously from the 3 bins at constant rate

Each capital letter, A through L, designates each 15 tons of material crushed, being crushed in alphabetical order and positioned as shown. Each small case letter, a through l, designates the fines associated with each 15 tons crushed. The trucks are designated 1 through 34 as in the order in which they were leaded.

Data

The following tables present the analytical results of the samples taken.

Minus $1\frac{1}{4}$" plus $\frac{1}{8}$" 70-foot bed as crushed into storage bins

Sample description 1)	Crushing plant sample No.	Fischer assay gal./ton
1st 15 tons crushed into bin #1 (A)	CPI-68	27.24
2nd " " " " bin #2 (B)	" -69	25.68
3rd " " " " bin #3 (C)	" -70	27.77
4th " " " " bin #1 (D)	" -74	27.50
5th " " " " bin #2 (E)	" -75	25.95
6th " " " " bin #3 (F)	" -78	Sample accidently destroyed
7th " " " " bin #1 (G)	" -79	25.90
8th " " " " bin #2 (H)	" -80	25.40
9th " " " " bin #3 (I)	" -81	26.70
10th " " " " bin #1 (J)	" -82	25.40
11th " " " " bin #2 (K)	" -83	27.50
12th " " " " bin #3 (L)	" -84	28.30
Average	-	26.67

1) Capital letters correspond to those on diagram under "Procudure".

Minus $1\frac{1}{4}$" plus $\frac{1}{8}$" 70-foot bed as withdrawn from storage bins

Sample description	Crushing plant sample No.	Fischer assay gal./ton
1st truck load of 34 withdrawn	CPI-92	24.36
2nd " " " " "	" -93	24.89
3rd " " " " "	" -94	25.42
4th " " " " "	" -95	25.15
5th " " " " "	" -96	24.36
6th " " " " "	" -97	25.68
7th " " " " "	" -98	24.10
8th " " " " "	" -99	25.94
9th " " " " "	" -100	25.94
10th " " " " "	" -101	24.89
11th " " " " "	" -102	25.94
12th " " " " "	" -103	25.94
13th " " " " "	" -104	26.98
14th " " " " "	" -105	26.21
15th " " " " "	" -106	26.21
16th " " " " "	" -107	26.98
17th " " " " "	" -108	26.21
18th " " " " "	" -109	27.24
19th " " " " "	" -110	26.74
20th " " " " "	" -111	26.21
21st " " " " "	" -112	27.24
22nd " " " " "	" -113	27.77
23rd " " " " "	" -114	27.50
24th " " " " "	" -115	27.77
25th " " " " "	" -116	29.09
26th " " " " "	" -117	27.77
27th " " " " "	" -118	27.77
28th " " " " "	" -119	27.77
29th " " " " "	" -120	28.03
30th " " " " "	" -121	27.24
31st " " " " "	" -122	28.30
32nd " " " " "	" -123	28.30
33rd " " " " "	" -124	28.30
34th " " " " "	" -125	28.56
Average		26.69

Table 2. - Screen analysis - Minus $1\frac{1}{4}$" plus $\frac{1}{2}$" 70-foot bed as crushed into storage bins

Sample description 2)	Crushing plant sample No.	-.131	-.185 to +.131	-.263 to +.185	-.371 to +.263	-.525 to +.371	-.742 to +.525	-1.05 to +.742	-1.25 to +1.05	Total %
1st 15 tons crushed into bin #1 (A)	CPI-68	2.3	1.4	0.9	4.2	18.5	28.2	41.4	3.3	100.00
2nd " " " " bin #2 (B)	" -69	3.2	1.9	1.3	3.2	15.4	23.7	37.8	13.5	100.00
3rd " " " " bin #3 (C)	" -70	2.8	0.7	1.4	4.1	15.2	29.6	36.5	9.7	100.00
4th " " " " bin #1 (D)	" -74	1.3	0.4	0.4	3.5	17.5	29.0	40.4	7.5	100.00
5th " " " " bin #2 (E)	" -75	0.6	0.6	0.6	2.6	17.5	28.7	39.7	9.7	100.00
6th " " " " bin #3 (F)	" -78	sample accidently destroyed								
7th " " " " bin #1 (G)	" -79	1.8	0.9	0.9	1.8	19.5	29.2	39.7	6.2	100.00
8th " " " " bin #2 (H)	" -80	1.6	0.8	0.8	2.5	17.5	30.0	41.8	5.0	100.00
9th " " " " bin #3 (I)	" -81	2.8	1.4	1.4	4.2	15.5	26.8	46.0	1.4	100.00
10th " " " " bin #1 (J)	" -82	1.1	1.1	1.1	2.2	15.6	24.4	42.3	12.2	100.00
11th " " " " bin #2 (K)	" -83	2.0	1.0	1.0	3.0	14.9	26.7	44.5	6.9	100.00
12th " " " " bin #3 (L)	" -84	4.6	2.8	4.6	6.4	14.7	22.0	38.5	6.4	100.00
Average		2.20	1.19	1.32	3.44	16.51	27.12	40.78	7.44	100.00

1) Cumulative screen analysis of minus $1\frac{1}{4}$" plus $\frac{1}{2}$" 70 foot bed as crushed into the storage bins

-.131	-.185	-.263	-.371	-.525	-.742	-1.05	-1.25
2.20	3.39	4.71	8.15	24.66	51.78	92.56	100.00

1) Based on averages from above table.

2) Capital letters correspond to those on diagram under "Procedure"

Minus $1\frac{1}{4}$" plus $\frac{1}{2}$" 70-foot bed as withdrawn from storage bins

2nd truck load of 34 withdrawn	CPI-93	1.9	2.4	1.2	5.6	21.1	28.6	33.0	6.2	100.00
11th " " " " "	" -102	1.8	1.2	1.2	4.9	17.0	33.6	33.6	6.7	100.00
21st " " " " "	" -112	2.2	1.4	0.7	3.6	15.3	32.2	35.1	9.5	100.00
31st " " " " "	" -122	2.5	1.7	1.7	4.2	11.7	20.0	44.0	14.2	100.00
Average		2.10	1.68	1.20	4.58	16.27	28.60	36.42	9.15	100.00

3) cumulative screen analysis of minus $1\frac{1}{4}$" plus $\frac{1}{2}$" 70-foot bed as withdrawn from storage bins

-.131	-.185	-.263	-.371	-.525	-.742	-1.05	-1.25
2.10	3.78	4.98	9.56	25.83	54.43	90.85	100.00

3) Based on averages from above table

NOTE: Only 4 truck loads of 34 blended were analyzed for screen size because of lack of time.

Table 3. - Screen analysis and Fischer assay
Minus ¼" fines 70-foot bed while producing minus 1¼" plus ¼" product.

Sample description 2)		Crushing plant sample No.	-.065	-.093 to +.065	-.131 to +.093	-.185 to +.131	-.263 to +.185	-.371 to +.263	-.500 to +.371	total %	Fischer assay gal./ton
Fines while crushing 1st 15 tons of 180 tons	(a)	CPI-71	27.6	9.4	9.4	13.4	16.5	18.2	5.5	100.00	25.42
" " " 2nd " "	(b)	" -72	21.8	7.8	8.3	14.6	15.5	18.4	13.6	100.00	24.89
" " " 3rd " "	(c)	" -73	22.1	8.6	8.6	12.9	18.2	21.5	8.1	100.00	25.15
" " " 4th " "	(d)	" -76	30.0	9.0	9.0	12.4	14.1	17.6	7.9	100.00	23.06
" " " 5th " "	(e)	" -77	21.5	7.9	8.7	15.9	17.5	20.6	7.9	100.00	26.21
" " " 6th " "	(f)	" -85	19.9	6.6	9.6	15.4	19.1	23.5	5.9	100.00	27.20
" " " 7th " "	(g)	" -86	29.5	8.2	9.8	15.0	16.5	17.2	3.8	100.00	24.90
" " " 8th " "	(h)	" -87	27.0	4.7	10.1	15.5	17.8	20.2	4.7	100.00	24.60
" " " 9th " "	(i)	" -88	29.0	7.7	10.3	14.8	17.5	16.2	4.5	100.00	24.60
" " " 10th " "	(j)	" -89	30.5	8.7	11.2	14.9	14.9	15.5	4.3	100.00	24.10
" " " 11th " "	(k)	" -90	28.9	8.3	9.8	14.4	15.9	18.2	4.5	100.00	24.40
" " " 12th " "	(l)	" -91	29.4	8.5	10.5	11.1	16.4	18.5	5.6	100.00	25.40
Average		--	26.44	7.95	9.61	14.19	16.66	18.80	6.36	100.00	24.99

1) Cumulative screen analysis of minus ¼" fines 70-foot bed while producing minus 1¼" plus ¼" product.

-.065	-.093	-.131	-.185	-.263	-.371	-.500
26.44	34.39	44.00	58.19	74.85	93.65	100.00

1) Based on averages from above table

2) Small case letters correspond to those noted on diagram under "Procedure".

Crushing Information:

1) Total minus 1 1/4" plus $\frac{1}{2}$" produced = 180.72 tons

2) Total minus $\frac{1}{2}$" fines produced = 93.20 tons

3) Total crushing time = 11 hrs., 0 min.

Then, Fines loss

$$= \frac{93.20}{\frac{180.72+9320}{.99 \quad 4)}} \times 100 = 33.68\ \%$$

and, Crushing rate

$$= \frac{180.72}{11} = 16.43 \text{ tons/hr.}$$

1) Weight obtained by use of conveyor scales on conveyor No. 2.

2) Weight obtained by use of conveyor scales on conveyor No. 9.

3) Represents total actual crushing time - obtained by use of stop watch.

4) Assuming 1 percent dust loss + loss of total mine run handled.

Table 5.

Summary of average Fischer assay values (compiled from foregoing tables)

Average of:

1)	1 - Minus 1 1/4" plus $\frac{1}{2}$" as crushed into the storage bins	26.67 gal./ton
	2 - Minus 1 1/4" plus $\frac{1}{2}$" as blended into the 34 truck loads	26.69 "
	3 - Minus 1 1/4" plus $\frac{1}{2}$" as a composited sample of the 34 truck loads	26.74 "
	4 - Minus $\frac{1}{2}$" fines to waste while producing the minus 1 1/4" plus $\frac{1}{2}$"	24.99 "

1) This average is not absolutely correct since one of the 12 samples on which the average should be based was destroyed.

CONCLUSION

No attempt has been made to analyze or make any conclusions concerning the analytical results herein, but merely to present the methods used for preparation and sampling and the tabulated results for sake of permanent record.

W.H. ECKERSON

Report on the testing of Colorado (Green River) Oil Shale in the HG-retort at Kvarntorp, Sweden.

Introduction.

In order to study the behaviour of Colorado shale in the Swedish shale retorts an investigation was arranged and performed in cooperation between U.S. Bureau of Mines, the "Denver Group" (headed by Mr. Carl Norgren) and the Swedish Shale Oil Company.

The tests were made at the Swedish Shale Oil Co:s works at Kvarntorp, Sweden. A quantity of about 140 tons of shale was prepared and shipped to Kvarntorp, packed in tight bags, by U.S. Buraau of Mines. A detailed report on the mining, crushing, screening and mixing of the shale is included as an appendix to this report.

The laboratory tests on the shale were made during 1951. In accordance with the conclusions from the obtained results it was determined that the full-scale retorting tests should be performed in the HG-retort system. One of the retorts of the HG-oven was selected for this purpose and was equipped with separate condensing equipment. The full-scale retorting was made in February, 1952, in the presence of Mr. John W Savage, representing Savage Shale Oil Development Company and the Denver Group and Mr. R. Beverly, representing U.S. Bureau of Mines.

The results of the runs are presented in this report, which contains the following parts:

1. A summary of the laboratory investigations on the Green River oil shale.
2. A short description of the HG-retort.
3. Description of the test runs with Green River oil shale.
   a) The retort and the condensing system.
   b) Sampling. Methods of analysis.
   c) The test runs: operating data; results of analysis; yield; heat and material balances; operating experience.
4. Summary of the test runs.

1. Summary on the investigations on Green River oil shale at the pyrolysis department of the laboratory.

Samples of the shale were taken out from three arbitrarily chosen bags and assayed according to Fischer. As they showed consistent properties the further investigation was done on one of the samples.

Results:

Fischer assay:
Oil 9,7 % by weight
Water 1,0 % "
Shale coke 87,5% "
Gas 18,1 liter/kg

Ash content: 67,9 % by weight. The melting point of the ash is lower than that of Kvarntorp shale ash.

Elementary analysis:
C 16,55 % by weight (including 4,48 % C as carbonate)
H 1,89 %
S 0,41 %

Heat value (gross): 1305 kcal/kg

Standard pyrolysis.

5 kg of the oil shale (size 10–20 mm) was heated electrically in a steel retort to 550°C in 24 hours (diagram 1), while the production of oil, gas and water was measured (Diagram 1). The following amounts of products were obtained:

oil: 107 ml/kg — shale coke: 84,6 % by weight

water: 1,9 % by weight — gas: 23,5 liter/kg
(0,7 % at temp:s lower than 250°C)

Properties of the products:

Oil:
Spec. gravity (aver.) 0,879 g/ml (diagram 3)
Sulphur: 0,74 % by weight
Iodine number: 75
Pour point: +19°C
ASTM-distillation: See diagram 4.

Gas:
Composition (of total). See also diagram 2.

H_2S	5,0 % by volume		
CO_2	11,3 %		
CO	3,3 %		
H_2	39,2 %		
N_2	7,8 %		C_1 22,2 % by volume
C_nH_{2n}	4,5 %	including	C_2 5,6 %
C_nH_{2n+2}	28,5 %		C_3 3,4 %
			C_4 1,7 %
			C_{5+} 0,5

Heat value (net, calculated): 4290 kcal/Nm³

Shale Coke: Elementary analysis: $C = 9,37$ % by weight (incl. 5,1 % C as carbonate)

$H = 0,31$ %

$S = 0,49$ %

Ash content = 76,1 %

Heat value (gross): 100 kcal/kg (measured)

During the pyrolysis the shale coke had partly baked to hard but brittle cemented pieces.

Water: Phenol content: 0,03 g/liter

Ammonia content: 10,6 g/liter

Calorific balance: Basis 1 kg oil shale

In: 1305 kcal	Out: oil	1070 kcal
	shale coke	86
	gas	101
		1257
	difference	48
		1305 kcal

Comparison with Kvarntorp oil shale.

The "oil content" of Green River oil shale is about twice as high as that of Kvarntorp shale.

The heat value of Green River spent shale (shale coke) is very low and is certainly too low for performace of the pyrolysis in the Kvarntorp-retort. Its baking tendency is another reason why the use of the Kvarntorp-retort is doubtful.

Compared with Kvarntorp oil the Green River oil has a low sulphur content, a very high pour point because of its high wax content, and the high refractive value indicates a high precentage of aromatics.

The gas contains much less H_2S, and the pyrolysis water has a higher NH_3-content.

2. Description of the HG-retort, and how it works with Kvarntorp shale.

The design of the retort is clear from the drawings. The slightly conical retort (upper diam 600 mm, lower diam. 720 mm) is in its lower part made of chamotte bricks, and in the upper part of chrome-alloyed iron. The retort-volume is about 3 m^3 (~3 tons shale). The hopper above is connected to the retort through an oil-seal, and holds about 6 tons shale. The top of the hopper is covered with a lid forming a water seal with the hopper. The hopper is charged from a belt conveyor (steel) common to all 72 retorts of the bench. Low pressure steam is injected as a seal against atmosphere during the charging operation. A rotating arm (with controllable rate) on a plate discharges the retort to a hopper which is intermittantly emptied to a car, carrying the coke to the coke combustion plant. The pyrolysis gases from all retorts are sucked off through a pipe by one suction-blower.

Superheated steam is injected in the lowest part of the retort in order to reduce the vapor pressure (steam distillation) and the retention time of the oil vapors in the hot pyrolysis zone. The steam also serves the purpose of sealing the retort from incoming air during the discharging of the hopper.

Each retort has one gas-burner, where end gases from the light hydrocarbon recovery plant are burned. The flue gases pass through a helical canal around the retort and then through a superheater for steam (common to four retorts). Part of the flue gases are recirculated to the gas-burner by a blower in order to save the chamotte bricks and to increase the gas velocities.

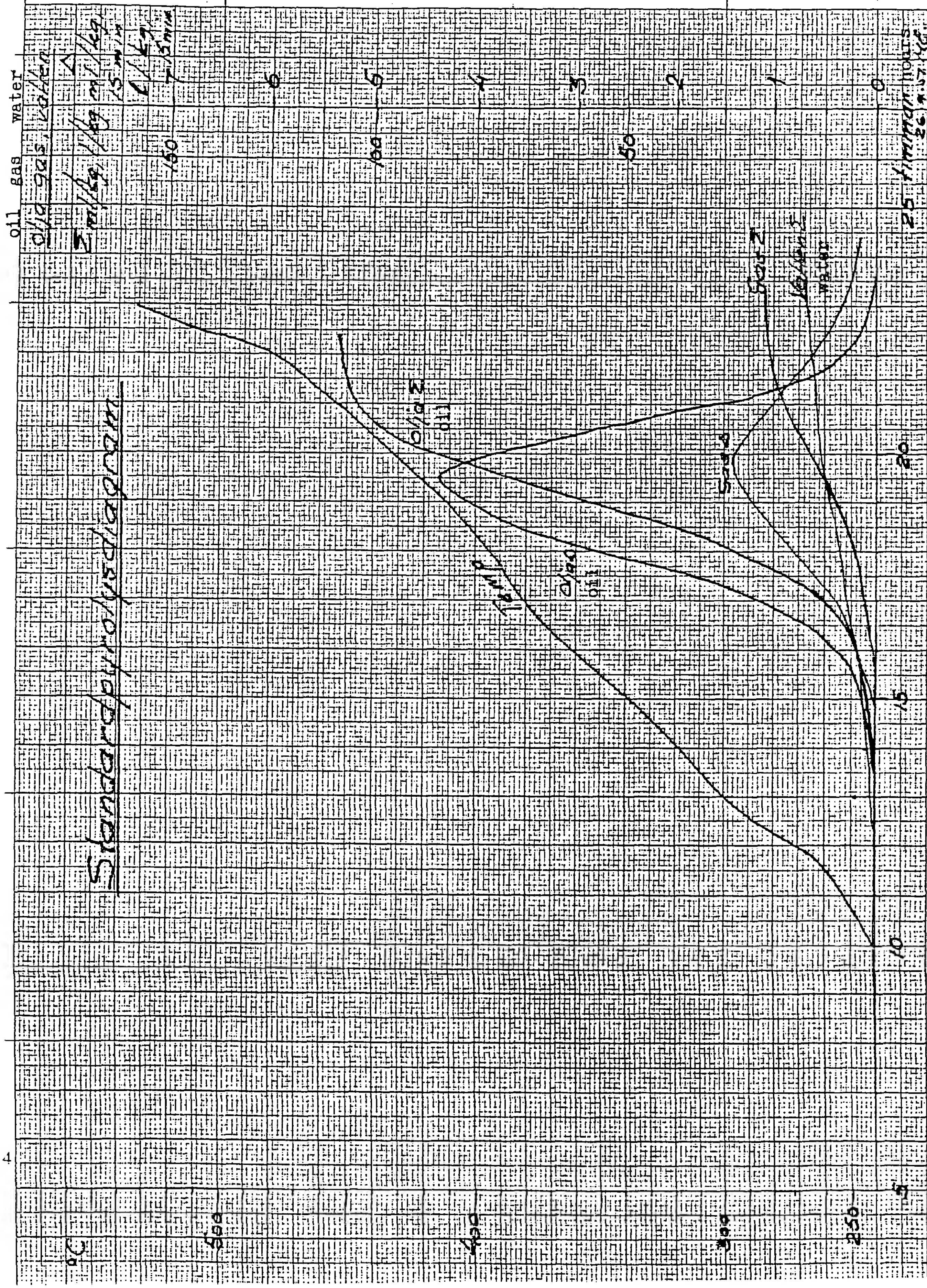
The temperature of the retort is controlled by two pyrometers in the flue gas canal outside the retort, one (A-point) just behind the gas-burner inlet and one (C-point) 2,80 meters above the A-point.

Normal operating data are: Charging raw shale: every fourth hour, in total 11 metric tons (size 27-70 mm) per retort and 24 h. Temperatures: A-point ~1000°C, C-point ~750-800°C. Discharging the coke hopper: every hour. Consumption of low pressure steam (saturated, 120°C): 120 kg/h. Consumption of fuel gas: 34 m^3/h. Temperatur of recirculated combustion gases: 210-250°C. Vacuum in the discharge pipe for pyrolysis gases: 20 mm water.

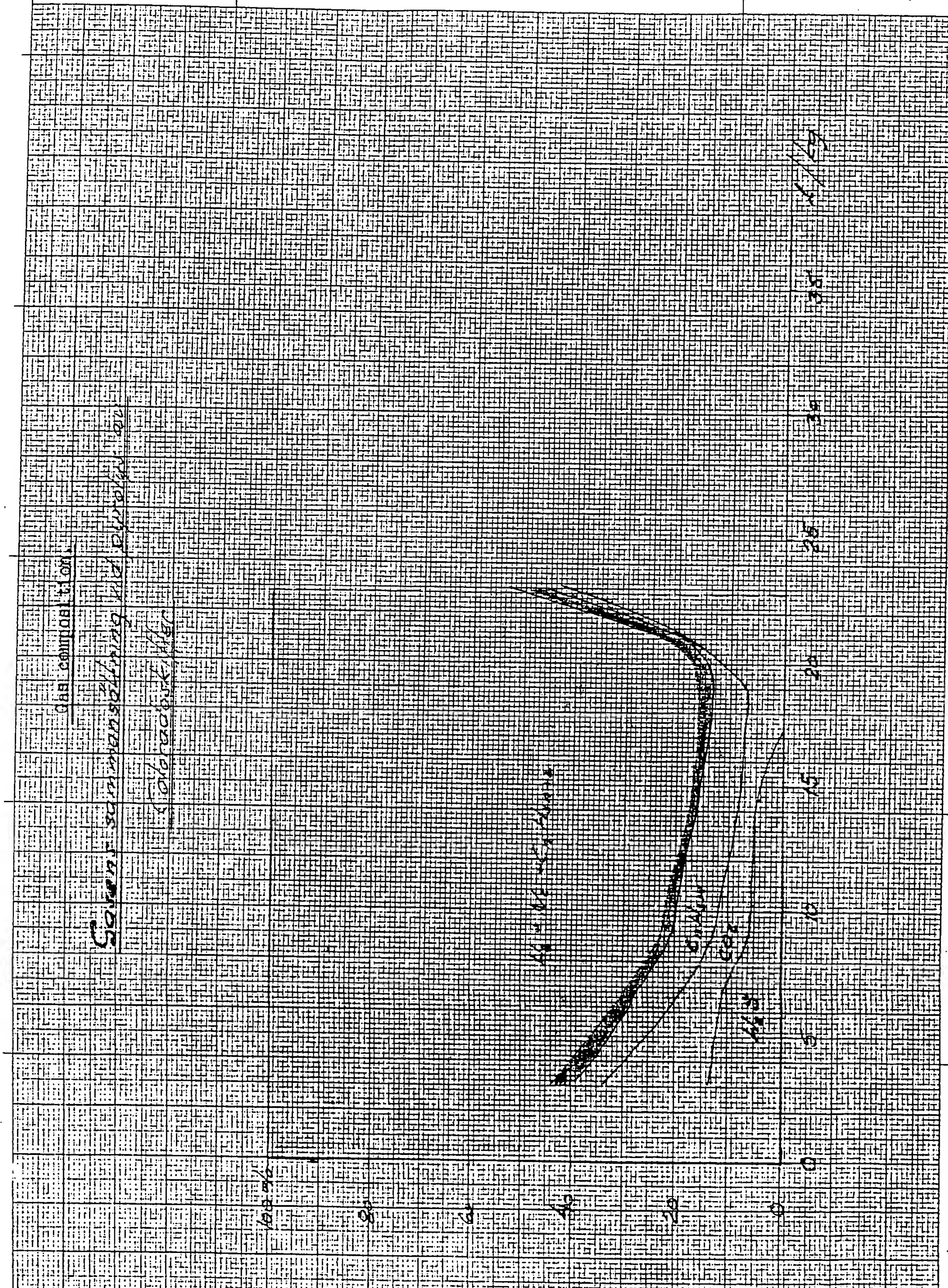
The following average consumption and production data were obtained during a normal production period (1.9. 1951 - 29.2. 1952).

Consumption:	Per retort and hour	Per metric ton of raw shale
Raw shale	460 kg	1000 kg
Steam (satd., 120°C)	121 kg	262 kg
Fuel gas (à 3500 kcal/m^3)	34 m^3	74,5 m^3
Corresponding calories	119.000 kcal	259.000 kcal
Cooling water (mostly circulated water from cooling towers).	4,15 ton	9,0 ton

Pyrolys-lab.	Pyrolys av Colorado-skiffer.	4.10.1951.



Pyrolys-lab.	Pyrolys av Colorado-skiffer.	4.10.1951.



SKIFFEROLJE A.-B. Fyrolys-lab.	Pyrolys av Colorado-skiffer.	Diagram 3 Rap. Lj- 107 4.10.1951.

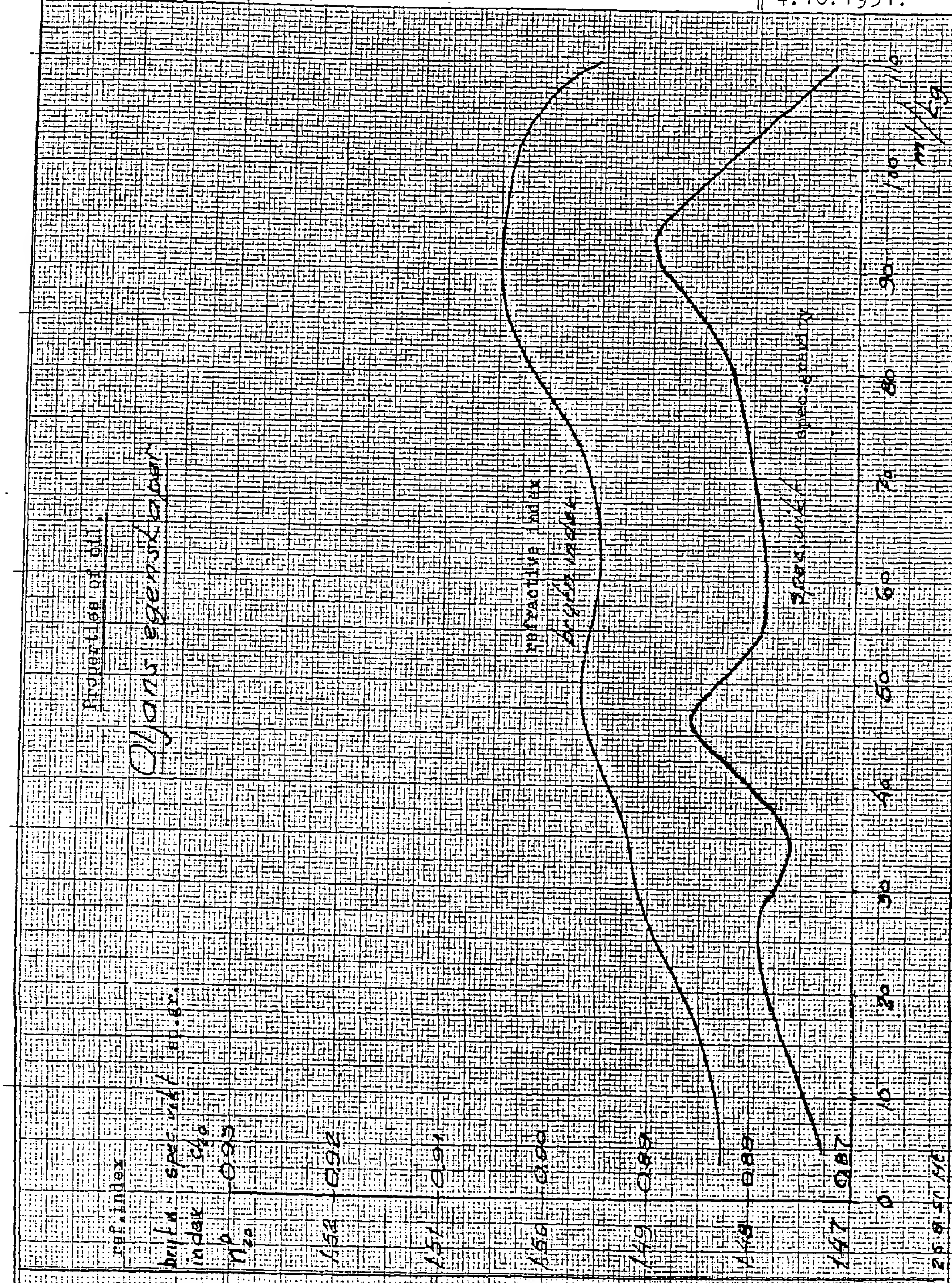


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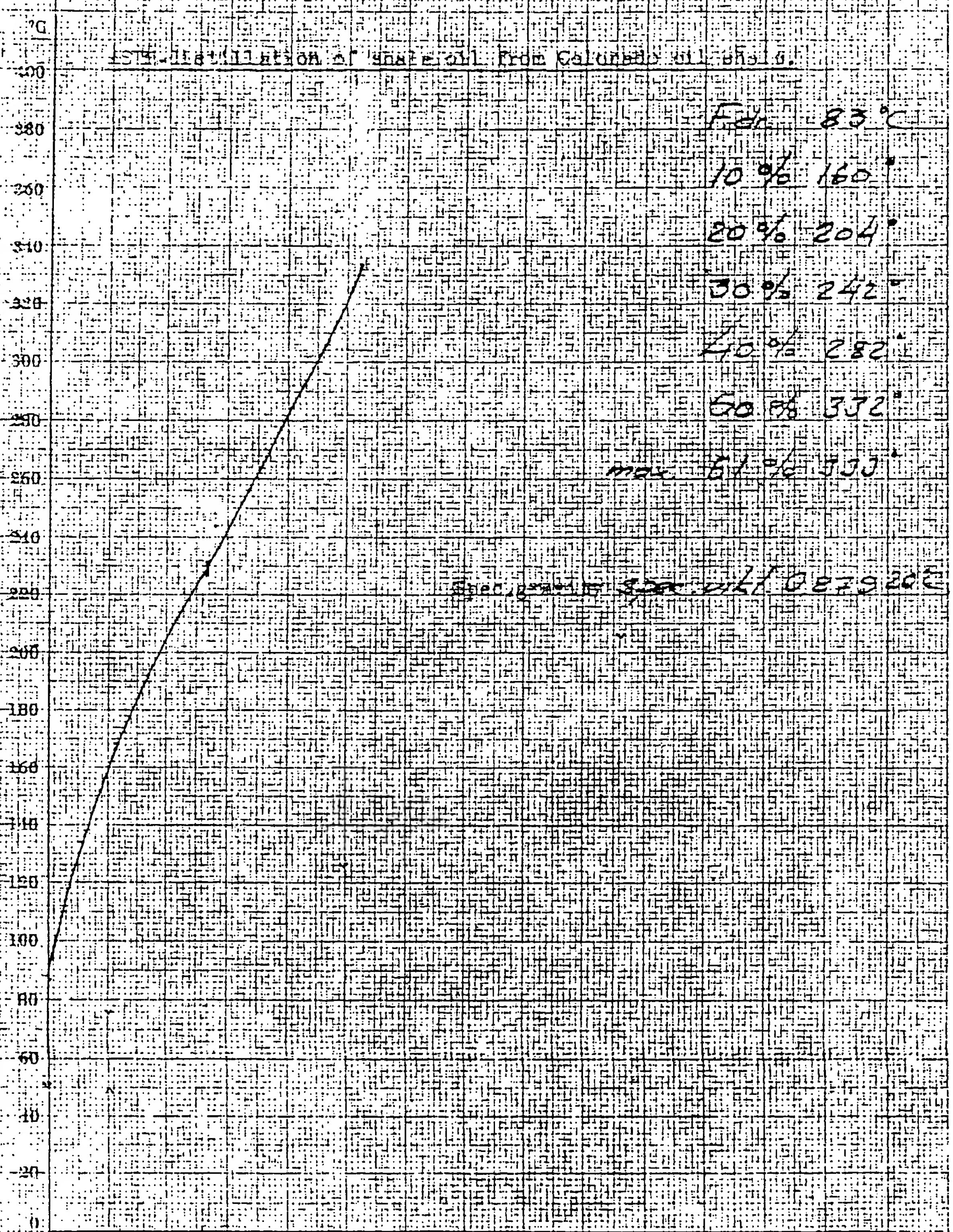
Diagram nr 4

ASTM-destillationskurva för skifferolja från Colorado, USA

Tillhör rapport nr 107 från Pyrolyslaboratoriet



Pl. 101. 5000. 6. 43.

3/10 61 HE

Production:	Per retort and hour	Per metric ton of raw shale
Crude oil	20,5 kg	44,6 kg
Light gasoline	3,4 kg	7,4 kg
Total oil	23,9 kg	52,0 kg
Crude gas	39 m^3	84,5 m^3

Yield: The average "oil content" of the shale according to the Fischer assay was 5,75 % by weight. The total yield of oil was thus 90,6 % of the Fischer value.

3. The test runs with Green River oil shale.

a) The retort, the condensing system and its control.

The retort chosen for the tests was situated in the middle of the 72 retort bench.

As the size of the Green River shale, 13-32 mm, was much smaller than that of Kvarntorps shale, 27-70 mm, the discharge mechanism had to be reconstructed. A trial without alterations resulted in free fall of the shale through the retort. The alterations, which are clear from the drawing 13-10, caused that the through-put could not be raised to more than 7 tons/24 h, although the speed of the rotating arm was increased from $\frac{1}{5}$ to 1 revolution/min. This depended on too small an opening above the arm and on the properties of the spent shale (small pieces and much dust in which the arm did not work efficiently).

An expected greater pressure drop because of the smaller size of the Green River shale was meant to be counteracted by placing an open 4" tube of 6 m length inside the retort. Its upper end was near the pyrolysis gas discharge pipe, and the tube was supported by three rods attached to the top of the hopper. The tube, however, became clogged by coked dust and oil as inspection after the tests showed, and its role during the test was supposingly none.

A flow sheet for the retort and the condensing equipment is shown in drawing nr. 13-199. The pyrolysis gases went through a 5" pipe to a scrubber (drawing nr 13-197), where they were counter-currently washed with water, and then to a tube-condenser, where they were cooled to 10°C or lower. The gas flow was caused by a suction blower after the tube condensor, and from the blower the gases went to a flare.

The water and oil from the scrubber were delivered to a settling tank from which part of the water-oil suspension was circulated to the top of the scrubber as wash liquid, and part flowed by free over-flow to a second tank, where oil and water separated. The scrubber-water was cooled partly indirectly

by a coil and partly directly by injection of cool water before the circulating pumps. From the seperator the oil flowed to a third tank, where it was collected and measured. The water was pumped away, but could be measured intermittently in a container with known volume outside the tank. The separator and the collecting tank had coils for steaming at cold weather.

The condensate from the tube condensor flowed down to the second tank, (the separator).

Condensate of oil in the pipes after the tube condensor was drained through a valve and returned to the second tank.

The shale was transported to the retort-hopper by the belt-conveyor from a container in which the sacks had been emptied. Its volume was 1,6 m^3 (~35 sacks). The shale was weighed by a band-scale, and the weight was checked by counting the sacks and evaluation of their net average weight. The spent shale was not weighed.

For the operation and control of the plant there were installed some orifice flowmeters, vacuum- and pressure gauges and thermometers (see drawing 13-199). All measurements and readings were manual. The retort temperature was measured at the points A and C outside the retort. The temperature of the circulated flue gases was measured at the burner inlet.

The injection of superheated steam was controlled by measuring temperature, pressure and amount (orifice). The amount of fuel gas was determined by an orifice meter, and the amount of uncondensable pyrolysis gas was measured by an orifice after the blower. The measure-points for temperatures and vacuum in the condensing system are shown in the flow sheet.

The amount of oil was measured in the third tank by measuring the depth of the oil layer after emtying the separating tank to a fixed level.

a) Sampling. Methods of analysis.

Raw shale: At every charging operation a sample of some kgs of shale was taken from the belt conveyor. The samples during a 24 hour-period were collected mixed, and divided. The following analysis are performed: Fischer assay (according to Fischer-Schrader), moisture content, elementary analysis on C, H (semi-micro, Reilen-Weinbrenner apparatus), S (Grothe-Krekeler and gravimetric determination of SO_4^{2-}) and C as carbonate (HCl-treatment and measuring the volume of CO_2), gross heat value (bomb-calorimeter) and ignition loss.

Spent shale(coke): At every discharge of the hopper some kilograms of coke were taken aside. The samples for a 24 hour-period were mixed and analyzed in the same respects as the raw shale. - Appreciation of the temperature of the coke was done by direct measurement in a pile of just discharged coke.

Shale oil: After every test period a general sample was taken of the collected oil production in tank 3. The content of the tank was stirred befor sampling.

Analysis (according to ASTM-standards): Spec. gravity (hydrometer), ASTM-distillation, water content (distillation with gasoline), pour point, elementary analysis of S, heat value (one sample). The viscosity was determined on two samples (Vogel - Ossag).

Water: Samples were occasionally taken out (no general samples were collected) and analyzed for NH_3- and oil content (extraction with ether).

Pyrolysis gas: Samples were taken at the orifice every second hour for determination of CO_2+ H_2S and O_2 and every eight hour for complete Orsat-analysis and determination of the heat value (Junker-calorimeter). Twice the composition of the hydrocarbons was evaluated through distillations in Podbielniak apparatus.

Fuel gas: Determination of the heat value (Junker-calorimeter) was performed every eight hour, and complete Orsat-analysis twice.

Flue gases: Complete Orsat-analyses were done twice on samples taken after the recirculation blower.

c. <u>The test runs. Operating data, results of analysis, yields, balances, operating experience.</u>

The heating of the retort was started 44 hours before the beginning of the first test period. The following tests were made:

Test run nr.	Temp. at A °C	Steam admission kg/H	Duration of test hours hours
1	900	95	24
2	900	95	24
3	950	95	24
4	1000	95	24
5	950	55	24
6	950	85	72

All essential operating and production data are shown in tables 1-5 and graphically in fig.1-2. Temperatures are average for 4-hour periods, and steam, shale oil and gas in- and output for 8-hour periods. Readings were done at least every hour. The results of the analyses are found in tables 6-11.

<u>Operating.</u>

The variations in steam temperature and pressure were small and the same is valid for the temperature of the circulated flue gases.

The raise of the water temperature in the scrubber was 1-2°C.

The vacuum in the retort (at the gas discharge pipe) was kept constant at 30 mm water, but the vacuum in the condensing system was higher, ~80 mm water, as the retort-vacuum for convenience was regulated with a valve immediately after the retort. The pressure drop through the whole condensing system was about 6 mm water.

The gas production reached much higher values than expected and the orifice in the gas pipe had to be changed. The first test was run, however, with the earlier, narrower orifice, which caused too high a pressure drop in the pipe and superpressure and gas leakage in the retort, which must be remembered when studying the gas yield in test hr. 1.

Because of small untightnesses in the condensing equipment a certain inleakage of air was found, as seen from the analyses:

day	hour	immediately after the retort % H_2S+CO_2	% O_2	after the condensing system % H_2S+CO_2	% O_2
20.2.	11.oo	46.2	0.2	39.7	2.2
	12.oo	45.4	0.2	38.6	2.5
21.2.	04.1o	31.1	4.1	24.7	6.0
22.2.	16.15	40.0	0.8	32.2	1.2

The oxygen contents of the gas immediately after the retort depended on air inleakage during the charging of the retort and small untightnesses in the retort wall. The extremely high value of 4.1 % O_2 was caused by a temporarily blown-out water-seal.

All data on the pyrolysis gas have therefore been recalculated on air free basis. (No correction has been made for the part of air, which corresponds to oxygen, consumed in the hot retort zones. The recalculated gas analyses are thus not nitrogen-free.)

The variations in the temperatures A and C depended on occasional shortage of fuel gas, variations of its pressure and heat value etc. The hourly calorific input was calculated from heat values, determined every eight hour. Because of the variations in the gas composition the results must be regarded cautiously.

The two flue gas analyses made showed the presence of considerable amounts of combustible matter in spite of the large excess of air. Only about 80 % of the supplied fuel calories were thus utilized.

The shale throughput per eight-hour-shift was calculated from the number of sacks charged and their average net weight, determined by weighing 20 arbitrarily chosen sacks. The band scale registered a weight about 3 % too high and in the last 4 days even more.

The variations in the calculated throughputs depends partly on the difficulty of filling the retort to the same level every time, and partly on variations in the actual descending speed of the shale, due to small variations in the rotating rate of the discharge mechanismus.

gross sack weight, kg

51.0	52.1
50.2	47.6
49.7	49.4
49.0	50.7
53.0	53.9
49.5	50.7
50.7	49.2
50.6	50.4
53.4	48.5
51.8	50.2

aver. 50.55 kg (gross)

aver. 50.0 kg (net)

The greatest difficulty at the measurements of the oil amounts was to determine the level of oil-water interface in the second tank as it must be at the same place at start and end of the test. An emulsion of oil and water seemed to occur at the interface, causing inaccuracies, which are serious at so short test periods as 24 h.

Allthough the separation of oil and water in the second tank seemed to be good, it might not have been perfect. The water content of the oil was estimated on the oil sample from every test run, but the oil content of the water was determined only two times, arbitrarily chosen. They showed 0.7 and 2.5 g oil/ liter water, and as the amount of water is rather high(direct cooling!) usually ~300 l/h, the mentioned figures correspond to 5 resp. 18 kg oil/24 h.

Analysis results.

Raw shale. The average oil yield according to Fischer, 9,8 % by weight, agrees well with the value reported as average from Rifle (Sampling and crushing report), 10,1 % (26,3 gal/ton).

Some analyses were later checked, namely Fischer-assay on shale from test run 5 and elementary analysis on shale from test run 6. The variations were considerable, and we can see no other reason for this than heterogenous samples.

The coke from one Fischer test was analyzed for carbon and hydrogen whereby were found C = 7,31 and H = 0,18 % by weight. The spent shale from the HG-retort had a lower carbon content. The heat value of the spent shale from test run 3 seems to be too low with respect to its organic carbon content. As the accuracy of the heat value determinations is low at these low values, an average of 200 kcal/kg has been used for spent shale from all test runs in calorific balances.

The special sample from test run 6 consists of selected cemented pieces of spent shale. They contain, as expected, a higher percentage of organic material.

The discharged spent shale at the test runs was not weighed, but its weight can be estimated from ignition loss figures of raw and spent shale.

Test run	2	3	4	5	6
spent shale, % of raw shale	82,2	78,7	77,3	80,0	83,5

The degree of decomposition of the carbonates can be calculated from that estimation.

Test run	3	4	5	6
% decomposition of carbonates	40	58	44	13
% of organic C left in the spent shale	20	22	22	22

Shale oil. The oils from the different test runs were rather similar except the one from run 6, which had a higher API-gravity and a higher content of low-boiling constituents (more than 60 % distilles below 300°C).

Elementary analysis on oil from run 3: 84,6 % C, 12,04 % H and 1,5 % N.

The viscosity was determined at 100°F and 210°F for the oil of highest and lowest pour point (Table 8.).

The approximate wax content of these two oils was determined. 200 g oil was mixed with 500 ml acetone. The precipitated wax was 0,5 % by weight of the oil from test run 3, and 0,1 % of the oil from run 6.

A small refining test was made on gasoline ($< 200^{\circ}C$) from the ASTM-distillation of oil from run 6 by treatment with NaOH-solution and subsequent treatment with "Doctor" solution. Total S-content decreased from 0,88 % by weight to 0,79 % and to 0,78 %. S as RSH decreased from 0,044 % by weight to 0,004 % and to 0,002 %.

Pyrolysis gas.

The results of the Orsat analyses and the heat value determinations, corrected to air free basis, are summerized in table 12 as averages over each test run.

Table 12.

Average composition and heat value of uncondensable pyrolysis gas.

Test run	2	3	4	5	6
H_2S, % by vol.	1,8	1,0	1,1	1,1	1,5
CO_2	42,0	42,5	41,5	39,6	38,5
C_nH_{2n}	3,5	3,4	3,1	3,3	4,4
O_2	-	-	-	-	-
CO	3,8	4,8	5,5	6,5	3,9
N_2	6,1	5,6	4,0	4,7	5,1
H_2	34,5	35,6	37,0	36,3	36,6
C_nH_{2n+2}	8,9	7,4	7,6	8,4	10,1
W_{net}, kcal/Nm^3	3150	2960	2830	2930	3190
W_{gross}, "	3410	3320	3110	3200	3500

No tendency can be found in these figurse. Lower temperature seems to give a gas with a little higher heat value, but the variations between the different samples (table 10) are too great to permit reliable conclusions.

Fuel gas and flue gas. The fuel gas was burned with considerable excess fo air, the analyses indicating 50-60 %, which gives about 7 m^3 flue gas per m^3 fuel gas. The flue gas has $c_p \sim 0,33$ kcal/Nm^3, $^{\circ}C$ in the range 25-250$^{\circ}C$.

Yields, balances.

In Table 13 essential retoring and condensing data have been collected.

Table 13.

Retorting, condensing and production data.

Test nr.	1-2	3	4	5	6
Durations, h	48	24	24	24	72
Temp. A, °C	890	940	1000	945	940
" C, °C	715	765	800	770	745
" of recirc. flue gas, °C	232	236	230	235	242
Steam admission, kg/h	94	95	94	53 73	84
" temp., °C	343	342	335	314 335	339
" pressure atm. (gauge)	0,33	0,33	0,31	0,05 0,20	0,10
Raw shale charged, ton/24 h	6,70	6,8	6,65	4,35	6,60
Fuel gas consumed, Nm^3/h	33,5	36	41	35,5	34,5
- " , heat value, gross, $kcal/Nm^3$	4260	4440	4100	5000	4500
Fuel gas heat value, net, $kcal/Nm^3$	3880	4020	3710	4200	4100
Gas temp. before scrubber, °C	94	93	90	85	89
" " after tube condenser °C	7	6	7	6	7
Crude oil produced, l/24 h	465	478	574	410	381
Crude gas " , Nm^3/h	30,5	28,5	36,5	30	30
Water produced, l/h	~94	(120)	~93	~63	~93
Total water out, l/h	330	(390)	375	-	300
" " " , temp. °C	80	70	65	65	60
Crude oil, spec. grav.	0,902-0,895	0,899	0,890	0,893	0,873
" , gasoline content fr. < 200°C	20	16	19	18	24
Crude oil, heat value, kcal/kg	10134	-	-	-	-
Crude gas, gross heat value $kcal/Nm^3$	3390	3320	3110	3200	3500
Spent shale, heat value, kcal/kg	200				

Yield and calorific balance calculations are made in tables 14 and 15.

Table 14.

Yields (basis 1 metric ton raw shale)					
Test run	1-2	3	4	5	6
Crude oil, l/ton	69,5	71,5	86,5	94	58
- " - , weight % of Fischer assay	62	64	82	88	53
Crude gas, Nm^3/ton (air-free basis)	(112)	108	114	163	113
Spent shale, kg/ton(estimated)	820	790	775	800	835

Sensitive heat was fed to the system (retort and condenser) only as steam and was carried away as spent shale, flue gases and water (direct, indirect and pyrolysis water). The spent shale had a temp. of $\sim 250^{\circ}C$ when leaving the hopper, and its specific heat may be 0,25 kcal/kg, $^{\circ}C$. Thus about 50.000 kcal/ton raw shale was carried by the spent shale. The flue gases left with a temp. of $\sim 235^{\circ}C$ and carried sensitive heat as steam (difference between gross and net heat values per Nm^3 fuel gas) and as specific heat ($\sim 7 \times 0,33 \times 235$/ Nm^3 fuel gas). The heat content of pyrolysis and direct cooling water could be calculated from volume and temperature measurements (inlet temp. = $10^{\circ}C$). The temperature raise and the amount of water used for indirect cooling was not known. Because of incomplete combustion in the burners it was supposed that 20 % of the fuel gas calories were not utilized.

Table 15.

Calorific balances (basis 1 metric ton raw shale)

Calories input			Calories output		
		Test run 1-2			
Raw shale	1270 10^3 kcal/ton	63 %	Spent shale, x)	$(50+160).10^3$ kcal/ton	11 %
Steam	220 "	11 %	Crude oil	620	31 %
Fuel gas (gross)	510 "	26 %	Crude gas	380	19 %
Total	2000 "	100 %	Water xx)	90	5 %
			Flue gas	120+100	11 %
			Losses and not measured	480	24 %
			Total	2000	100 %
		Test run 3			
Raw shale	1360.10^3 kcal/ton	64 %	Spent shale	$(50+160).10^3$ kcal/ton	10 %
Steam	220	10 %	Crude oil	650	30
~~Flue~~ Fuel gas (gross)	560	26 %	Crude gas	360	17
Total	2140	100 %	Water	~~90~~ 70	4
			Flue gas	120+110	11
			Losses and not measured	600	28
			Total	2140	100 %

x) = sensitive heat + heat value

xx)=water for direct cooling and pyrolysis water.

Test run 4.

Raw shale	1270.10^3 kcal/ton	= 61 %	Spent shale(50+160) $.10^3$ kcal/ton	=	10 %
Steam	220	10	Crude oil	770	37
Fuel gas(gross)	610	29	Crude gas	350	17
Total	2100	100 %	Water	~~80~~ 80	4
			Flue gas	140+120	12
			Losses and not measured	430	20
			Total	2100	100 %

Test run 5

Raw shale	1380.10^3 kcal/ton	= 56 %	Spent shale(50+160) $.10^3$ kcal/ton	=	8 %
Steam	210	8	Crude oil	840	33
Fuel gas(gross)	910	36	Crude gas	520	21
Total	2500	100 %	Water	~~20~~ 20	1
			Flue gas	240+180	17
			Losses and not measured	510	20
			Total	2500	100 %

Test run 6

Raw shale	1270.10^3 kcal/ton	= 62 %	Spent shale(50+170) $.10^3$ kcal/ton	=	11 %
Steam	200	10	Crude oil	510	25
Fuel gas(gross)	570	28	Crude gas	400	20
Total	2040	100 %	Water	~~60~~ 60	3
			Flue gas	120+110	11
			Losses and not measured	620	30
			Total	2040	100 %

The amount of heat required to decompose the carbonates ($MgCO_3$ and $CaCO_3$) is about 50.000 kcal/ton raw shale at 40 % decomposition.

Material balances have been calculated for carbon and sulphur.

Carbon-balances.

kg C per metric ton raw shale.

Test nr	2	3	4	5	6
IN: Raw shale:					
organic C	173	129	128	131	132
carbonate C		42	43	44	43
	173	171	171	175	175
OUT: Spent shale:					
organic C	62	26	29	28	30
carbonate C		25	17	24	34
Oil:	53	54	65	71	43
Gas:					
organic C	16	17	18	29	22
carbonate C	26	25	26	35	23
Water:					
carbonate C (no analyses)	-	-	-	-	-
	157	147	155	187	152
Diff.	16	24	16	-12	23

Sulphur-balances.

kg S per metric ton raw shale.

Test nr	2	3	4	5	6
IN: Raw shale	6,4	6,9	5,9	7,3	5,8
OUT: Spent shale	2,8	2,7	3,3	2,6	2,8
Oil	0,7	0,6	0,7	0,7	0,5
Gas	3,1	1,6	1,8	2,6	2,5
Water (no analyses)	-	-	-	-	-
	6,6	4,9	5,8	5,9	5,8
Diff.	-0,2	2,0	0,1	1,4	0

The yields show a tendency for higher yields of oil at higher temperatures. The temperature of the shale in the retort has supposingly been highest in test run 5 (depending on a 50 % longer retorting time) and lowest in run 6. (short warming-up period before the test period). Some accumulation of oil in the feed hopper may have contributed to the very low yield in test run 6 (inspection afterwards revealed oil in the hopper).

Inaccurecy in production data and sampling for the too short test periods and pre-periods with relatively small changes in retorting conditions may lead to false conclusions, and therefore we think it is more decent to calculate the over-all yield for all test periods. Thus for test periods 1-4 and 6 (together 7 ...).

Retorting: 6,65 ton/24 h at temp. A ~935° and C ~745°C

Yields: Oil 67,5 lit/ton shale (Sp.gr. 0,885=90; 21 % < 200°C)

corresp. to 61 % of Fischer assay

Gas 112 Nm^3/ton shale with gross heat value ~3400 kcal/Nm^3

The figure for %-yield will be increased by 4-5 % if including recoverable light gasoline from the gas.

The yield is low compared to that obtained at retorting Swedish shale. This can, however, be fully explained by regarding the lower retorting temperature and the size of the shale..

Operating experience from the whole plant (supported by calculations of heat transfer in beds of different particle sizes) shows that the rate of pyrolysis is less the smaller the shale pieces are. Of course this is counteracted by the 50 % longer pyrolysis time.

The calorific balances show that about the same amount of calories introduced with the raw shale came out as oil, gas and spent shale. There is a small difference between runs at high and low temperature, but temperature definitions were too inaccurate, and the calories not accounted for too many to permit any conclusions.

In none of the test runs the calories of the pyrolysis gas was enough to supply the heat necessary for heating the retort.
The retort system is thus not self-sustaining in calorific respect when retorting Green River oil shale.

Improvements in burner design and heat transfer surfaces may diminish the gap between consumed and produced gas-calories, and utilization of part of the calories in spent shale and flue gases may be possible.
This would, however, require additional research to get the retort system to fit better for an oil shale of Green River-type.

It is quite clear that retorting Green River shale in the HG-retort gives an easily condensable oil with much higher API-gravity and a considerably higher amount of gasoline than oil produced in retorts to which the heat is transferred directly to its interior by gases, and the pyrolysis gas has a good heat value and contains recoverable light hydrocarbons.

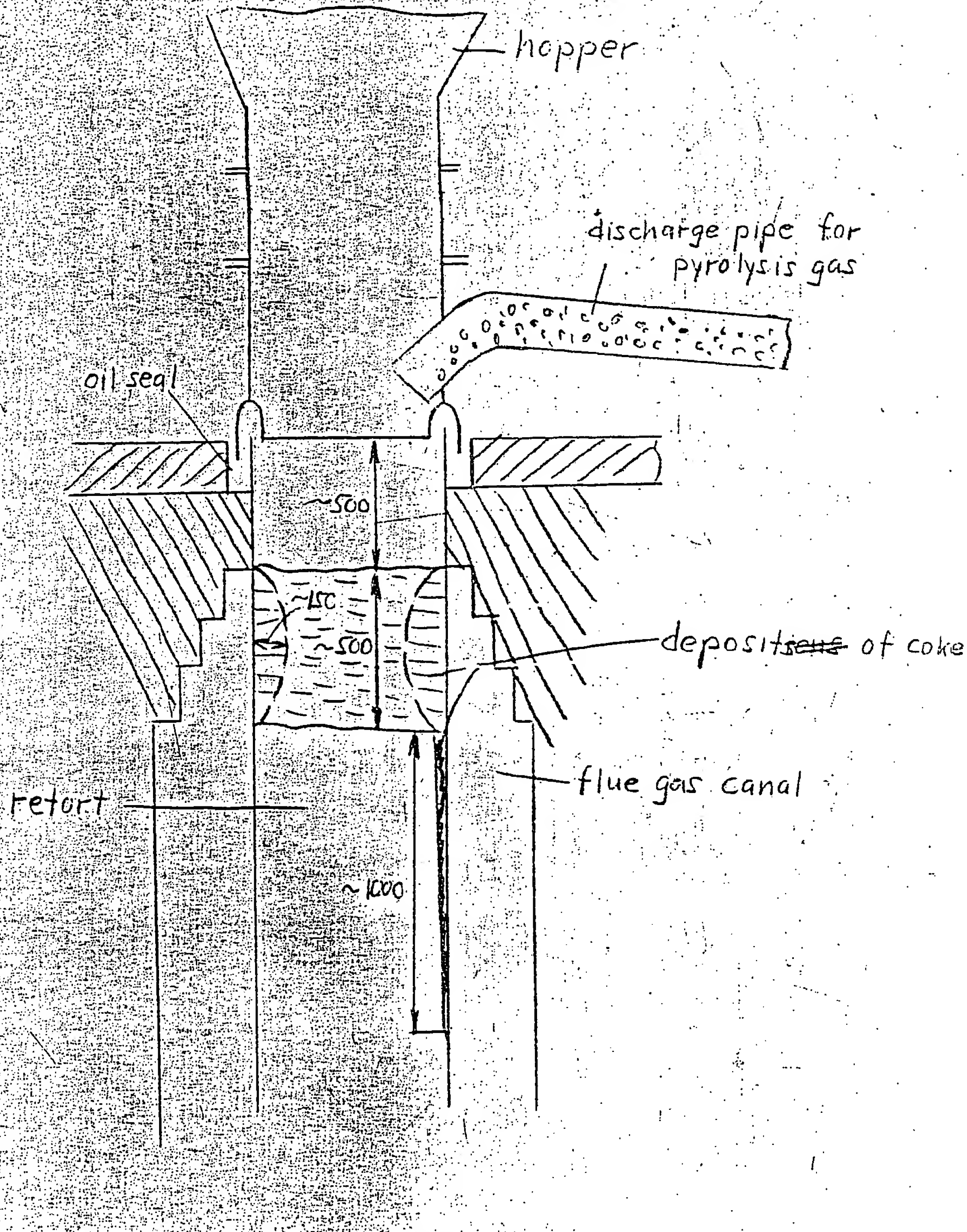


Fig. 5 Deposits ~~cone~~ in the retort after the tests

Operating experience.

The operating of the retort with Green River shale caused some troubles. After 6 days on line the throughput decreased. Lumps of cemented shale pieces appeared at the discharge mechanism. This occurred when the steam input had been decreased, but it is questionable if that was the cause. A gradually building-up on the walls at the top of retort and loosening later seems equally probable. Small cemented lumps could be observed during all test runs. The lumps finally stopped the discharging at the narrow openings. After the big lumps had been taken away the throughput was normal again.

Inspection of the retort revealed that deposits had been formed at the top of the retort proper (see fig.), and pieces of shale had been carried with the gas stream into the gas discharge tube, which was nearly filled with shale and oil to the first valve. This would probably not have occurred with bigger shale pieces. The deposits were probably formed by dust and condensed oil or oil that occasionally was sucked in from the oil-seal. The dust and oil coked to hard deposits including shale pieces on the hot retort-wall where the canal for the combustion gases ends. The raw shale contained some dust, and much dust was formed in the retort, which could be observed in the discharged material. It seems probably that these troubles would not occur if a bigger particle size of shale is used. It can be mentioned that deposits have been observed in retorts with Swedish shale which have been in service for many years.

The top of the retort and the hopper became warmer than by retorting Swedish shale, causing the water seal to run dry rather frequently.

The condensing equipment functioned well except for some cloggings of the pipes, as the weather was cold frequently, below 0°C, and the oil has high pour point.

4. Summary of the test runs.

Green River oil shale of size 12-32 mm (minus 1 1/4" plus ½") has been retorted in a HG-retort with a throughput of 6,7 tons/24 h (about 11 tons is normal for Swedish shale of size 27-70 mm) and at temperatures somewhat lower than for Swedish shale. The conditions were altered a little through 6 test runs.

The oil yield varied from 53 to 88 percent of Fischer assay. These yields are increased with about 4 % if the recoverable light gasoline from the gas is included. The spec. gravity of the oil was 0,873-0,902, and its gasoline-content (<200°C) 16-24 % by vol.

Uncondensable pyrolysis gas was produced to an amount of 108-163 Nm^3/ton raw shale and with a gross heat value of 3100-3500 kcal/Nm^3 (incl. light gasoline).

Calorific balances show that the retort is not self-sustaining with Green River shale, i.e. it consumes more fuel gas calories than it produces as uncondensable pyrolysis gas.

It is believed that the size of the Green River shale is largely responsible for the low yields and operating troubles. Operating experience with Swedish shale indicates that better yields and less operating troubles may be obtained with bigger sizes of the shale, although only new test runs can give definite answer. There is, however, not much hope that the retort system can become thermally self-sustaining with Green River shale.

Närkes Kvarntorp den 17.5.52.

SVENSKA SKIFFEROLJE A.B.

Laboratoriet

B. Stjärnberg

G. Salomonsson Åke Brandberg

Table 1.

Raw shale input (Calc. on basis of 8 hour periods).

Date	Shift	kg shale/h	Date	Skift	kg shale/h
Febr. 17	I	267	23	I	146
	II	301		II	256
	III	352		III	187
18	I	289	24	I	135
	II	265		II	48
	III	278		III	-
19	I	203			
	II	256	26	II	244
	III	276		III	271
20	I	267	27	I	249
	II	318		II	228
	III	312		III	292
21	I	307	28	I	365
	II	335		II	242
	III	281		III	289
22	I	196	29	I	280
	II	174		II	212
	III	182		III	250

Shift I 07-15
II 15-23
III 23-07

Table 2.

Steam input.

Date	Shift	kg steam/h	Temp. °C	Pressure (gage) atm	kg steam/ ton shale
Febr. 16	I–III	92	338	0,34	
17	I–III	93	342	0,33	303
18	I–III	94	346	0,32	339
19	I	98	330	0,33	483
	II–III	95	343	0,33	360
20	I		339	0,32	
	II	89	336	0,33	280
	III	94	330	0,30	295
21	I–II		338	0,31	
	III	53	311	0,05	170
22	I–II	53	314	0,05	287
	III	73	335	0,20	400
23	I	83	339	0,25	590
	II	99	346	0,20	385
	III	99	349	0,20	530
24	I	84	347	0,13	620
	II	81	343	0,13	1700
26	II	82	347	0,1	336
	III	82	350	0,1	302
27	I	83	345	0,1	333
	II	82	349	0,1	360
	III	87	351	0,1	298
28	I	84	348	0,1	230
	II	82	344	0,1	338
	III	87	345	0,15	300
29	I	82	344	0,1	292
	II	81	342	0,1	382
	III	85	329	0,1	340

Table 3.

Fuel gas input.

(calculated for $\gamma_{0,760} = 0,92\ kg/m^3$)

Date	Shift	Nm^3/h	Average heat value (gross) $kcal/Nm^3$	Average calorific input, kcal/h
Febr. 16	I	36,0		
	II	34,4	4450	158.000
	III	36,7		
17	I	33,6		
	II	32,0	4310	143.000
	III	33,6		
18	I	32,0		
	II	36,0	4210	143.000
	III	33,6		
19	I	35,2		
	II	36,0		
	III	34,8	4440	160.000
20	I	37,4		
	II	44,1		
	III	42,2	4100	169.000
21	I	43,4		
	II	38,1		
	III	36,7		
22	I	37,4		
	II	32,0	5000	177.000
	III	36,7		
23	I 07-10	36,6		
	10-16	0		
	II 16-22	34,4		
	III	28,0		
24	I	32,8		
	II	30,5	4530	
	II 23-02	22		
	02	0		
26	I 11-14	48,7		
	II	37,4		
	III	38,8		
27	I	32,8		
	II	34,8	4530	150.000
	III	32,0		
28	I	32,0		
	II	35,2	4600	160.000
	III	37,4		
29	I	34,4		
	II	36,0	4360	
	III	37,4		
March 1	I 07-16	35,2		

Table 4.

Oil production.

Date	Tim	liters of oil	liters/h
Febr. 17	05.00	0	
	12.30	122	16,3
	23.30	294	15,6
18	12.00	591	23,8
	19.00	739	21,2
19	02.30	907	22,4
	11.00	1047	16,5
	15.50	x)	-
20	01.25	1174	
	08.00	1338	24,0
	15.25	1516	24,0
	23.30	x)	-
21	04.45	1651	
	16.00	1868	19,3
	23.40	2093	29,3
22	06.30	2193	14,6
	01.45	2490	16,0
	06.30	2603	23,8
	03.00	2848	10,9
	21.25	3054	11,2

x) An amount pumped off unmeasured.

Table 4. (cont.'d)

Date	Time	liters of oil	liters/h
Febr. 26	11.55	153	
27	04.00	377	13,9
	08.20	452	17,3
	19	642	19,0
28	04.20	804	17,4
	07.55	888	23,5
	20.00	1082	16,1
29	08.20	1228	11,8
	18.00	1483	16,0
March 1	08.05	1693	14,9

Oil production during the test runs.

Test nr.	Period	oil, lit/24 h	lit.oil/ton shale
1	17/2 07-18/2 07	465	69,5
2	18/2 07-19/2 07		
3	19/2 16-20/2 16	478	71,5
4	20/2 23-21/2 23	574	86,5
5	22/2 07-23/2 07	410	94
6	27/2 08-1/3 08	381	58

Table 5.

Production of pyrolysis gas.

(The amount of gas is calculated with $\gamma_{0,760} = 1,15$ kg/m^3)

Date	Shift	Crude gas Nm^3/h	% O_2	Crude gas (air-free basis) Nm^3/h	Nm^3/ton raw shale
Febr. 17	I	(22,8)	2,5	(20,0	75)
	II	(24,7)	1,7	(22,6	75)
	III	(21,7)	1,8	(19,7	56)
18	I	(22,2)	1,7	(20,3	70)
	II	49,0	7,6	30,4	115 New orifice
	III	30,9	1,7	30,3	109
19	I	32,8	1,9	29,6	146
	II	34,3	1,7	31,4	125
	III	30,9	2,1	27,4	100
20	I	29,9	2,4	26,3	99
	II	37,9	2,0	34,1	107
	III	46,8	5,1	34,8	111
21	I	42,3	3,3	35,3	115
	II	41,1	1,1	38,8	116
	III	50,2	6,8	33,2	118
22	I	31,5	2,5	27,6	141
	II	32,8	1,3	30,6	176
	III	32,9 47,2	1,6 6,5	30,3 31,8	172
23	I	24,3	2,3	21,5	154
	II	18,0 25,6	2,6 2,5	15,5 22,4	135
	III	21,4	3,7	17,5	94
24	I	27,4	2,6	23,8	176
	II	25,0	2,7	21,6	450
	III	16,4	3,7	13,4	

Date	Shift	Crude gas Nm^3/h	Crude gas % O_2	Crude gas (air-fri basis) Nm^3/h	Nm^3/ton raw shale
Febr. 26	I	17	4,7	13	—
	II	18,2	3,7	14,8	
		40,5	10,3	20,1	74
		21,7	2,2	19,3	
	III	31,8	1,7	29,0	107
27	I	31,2	2,4	27,5	110
	II	29,2	1,8	26,6	107
	III	35,2	1,6	32,4	111
28	I	32,0	1,6	29,4	81
	II	32,1	1,5	29,7	123
	III	34,0	1,6	31,3	108
29	I	38,4	2,3	34,0	121
	II	32,9	2,0	29,6	140
	III	31,5	1,6	29,0	116
March 1	I	31,0	1,2	29,1	

Table 6.

Analysis of raw shale.

Test run nr.	0	1	2	3	4	5	6
Date	16/2 - 17/2	17/2 - 18/2	18/2 - 19/2	19/2 - 20/2	20/2 - 21/2	22/2 - 23/2	27/2 - 1/3
Time	07 07	07 07	07 07	16 16	23.30 23.30	06.30 06.30	08 08
Fischer assay:							
oil, % by weight	9,7	9,7	10,5	10,0	9,4	9,5 x)	9,6
coke, "	85,8	86,8	85,6	86,9	87,4	87,4 x)	87,3
H_2O, "	1,6	1,8	1,9	1,5	1,6	1,6 x)	1,9
Moisture "	0,2	0,3	0,2	0,2	0,1	0,2	0,3
Total C, % "	-	16,3	17,3	17,08	17,07	17,52	17,5 16,86 16,67
carbonate C "	-	-	-	4,21	4,29	4,35	4,30
H "	-	1,62	1,77	1,77	1,69	1,83	2,11 1,78 1,87
S "	0,63	0,63	0,64	0,69	0,59	0,73	0,58
Gross heat value kcal/kg	-	1200	1340	1360	1270	1385	1265

x) Average of

9,2	87,3	1,9
9,8	87,1	1,4
9,5	87,4	1,3
9,2	87,3	1,9
9,7	87,8	1,3

Table 7.

Analysis of spent shale.

Test run nr.	0	1	2	3	4	5	6	
Date	16/2 - 17/2	17/2 - 18/2	18/2 - 19/2	19/2 - 20/2	20/2 - 21/2	22/2 - 23/2	27/2 - 1/3	spec.
Time	07 07	07 07	07 07	16 16	23.30 23.30	06,30 07	08 08	sample
Fischer assay:								
oil % by weight	0,0	-	-	0,0	0,05	0,05	0,05	
coke % "	99,7	99,5	99,1	99,5	99,5	99,45	99,3	99
H_2O % "	0,0	0,5	0,8	0,5	0,5	0,5	0,7	
Moisture, %	-	-	-	-	-	-	-	
Ignition loss, % by w.	-	-	18,5	15,8	13,0	16,3	18,0	21,
total C, % by weight	-	7,5	7,5	6,45	5,95	6,62	7,66	10,
Carbonate C "	-	-	-	3,16	2,26	3,06	4,12	
" H "	-	0,41	0,31	0,23	0,27	0,25	0,26	0,
" S "	0,28	0,40	0,34	0,34	0,43	0,33	0,33	0,
Gross heat value kcal/kg	-	225	165	(35)	190	210	210	(27

Table 8.

Analysis of shale oil.

Test run nr.	0	1	2	3	4	5	6
Date,	16/2 - 17/2	17/2 - 18/2	18/2 - 19/2	19/2 - 20/2	20/2 - 21/2	22/2 - 23/2	27/2 - 1/3
Time	07 07	07 07	07 07	16 16	23.30 23.30	06.30 06.30	08 08
Sp.gr. at 20°C	0,889	0,902	0,895	0,899	890	0,893	0,873
" °API	27,7	25,4	26,6	25,5	27,5	27,0	30,6
ASTM-dist.f.d. °C	60	49	58	72	48	57	72
5 %, °C	146	149	140	144	146	149	143
10 %, °C	163	167	163	181	167	169	161
20 %, °C	I97	200	200	218	206	211	191
30 %, °C	231	237	231	256	241	246	220
40 %, °C	-	274	258	278	266	275	40% 247 50% 272 60% 297
Overdist. at 200°C (392°F)	21	20	20	16	19	18	24
" at 300°C (572°F)	-	49	48	46	54	49	61
H_2O, %	0,6	0,1	0,1	6,4	1,2	0,5	0,3
Pour point, °C(°F)	+12(54)	+10(50)	+8(46)	+14(57)	+12(54)	+5(41)	+4(39)
Gross heat value kcal/kg	-	-	10134	-	-	-	-
S,% by weight(gravim)	-	1,17	1,08	0,88	0,91	0,88	0,94
Viscosity at 100°F cSt	-	-	-	6,3	-	-	3,24
210°F cSt	-	-	-	2,00	-	-	1,22

Table 9.

Analysis of pyrolysis gas.

Test run nr.	0				1				2		
Date		16.2.		17.2.					18.2.		
Time	09.30	16.00 x)	18.00	01.00 x)	10.45	17.00	01.00	01.30	11.15	16.30	00.30
net W_l, kcal/Nm^3			2030	2350	2650	3020	2860		2980	1830	2380
gross W_u, "			2200	2600	2900	3300	3120		3260	1980	2560
H_2S, % by vol.	1,4	0,0		1,0	1,4	1,6		1,6	2,1	0,9	1,3
CO_2 "	34,2	30,8		33,8	35,0	40,0		35,2	38,7	21,5	38,7
C_nH_{2n} "	2,8	1,8		6,4	3,2	3,2		3,4	3,6	2,0	2,1
O_2 "	3,2	4,8		1,6	2,0	1,2		3,2	1,0	10,4	2,4
CO "	3,2	2,8		2,4	2,8	4,0		2,8	3,4	1,6	4,1
N_2 "	22,9	27,2		23,5	17,0	8,6		17,1	9,4	40,0	16,5
H_2 "	24,8	26,4		25,6	31,0	32,4		29,0	32,6	18,0	29,6
C_nH_{2n+2} "	7,5	6,2		5,7	7,6	9,0		7,7	9,2	5,6	5,3

x) Aspirator used.

Table 9. (cont.'d)

Analysis of pyrolysis gas.

Test run nr.	3				4					5		
Date	19.2.		20.2.		21.2.					22.2.		
Time	17.15	00.30 x)	10.30 x)	16.00	01.30	11^{45}	14^{30}	16.30	01.30	11.00	16.45	00.00 x)
net W_1, kcal/Nm^3	2800	2520	2770	2750	2140	2130		2590	1840	2780	2920	2380
gross W_u, "	3040	2780	3040	3010	2380	2360		2800	1970	2950	3270	2610
H_2S, % by vol.	1,1	0,2	0,4	1,9	0,7	0,8	35,0	1,1	0,4	1,2	1,0	0,7
CO_2 "	38,3	39,8	38,8	38,7	29,7	31,6		40,4	23,8	34,4	35,6	39,5
C_nH_{2n} "	3,0	3,0	3,4	3,0	2,0	2,6	3,0	2,7	2,1	3,6	3,4	2,0
O_2 "	1,6	1,4	2,0	1,8	6,0	4,4	2,8	1,4	7,7	1,6	1,4	1,9
CO "	4,0	5,0	4,0	4,6	3,8	5,0	4,2	5,0	5,4	7,4	5,6	5,1
N_2 "	15,0	10,4	9,8	11,0	16,1	18,0	18,6	7,2	30,4	10,0	11,6	10,9
H_2 "	32,4	32,4	33,2	32,6	24,8	30,8	29,8	36,8	25,0	33,2	32,8	34,2
C_nH_{2n+2} "	4,6	7,8	8,4	6,4	5,9	6,8	6,6	5,4	5,2	8,6	8,8	5,7

x) Aspirator used.

Table 9. (cont.'d)

Analysis of pyrolysis gas.

Test run nr.								6					
Date	24.2.		25.2.		27.2.			28.2.				29.2.	
Time	06.00	17.00 x)	01.30 x)	10.00	17.15	23.15	08.30	16.30	18.00	23.30	11.15	17.00	24.[illegible]
net W_1, kcal/Nm^3		2060	1330	2580	2720	2770	2820	3230	-	3040	2840	2820	312[illegible]
Gross W_u, "		2270	1500	2840	3020	3100	3060	3490	-	3320	3160	3100	348[illegible]
H_2S, % by vol.	0,9	0,6	0,8	1,1	1,0	1,1	2,0	1,4		1,4	1,7	1,3	1,4
CO_2 "	39,7	42,2	36,2	38,9	34,4	33,9	34,0	36,8	36,2	36,0	32,7	31,1	36,[illegible]
C_nH_{2n} "	1,4	1,8	0,8	3,6	3,2	4,4	4,2	4,0	4,2	4,6	4,0	3,4	4,[illegible]
O_2 "	3,2	1,6	3,6	1,2	2,0	1,8	1,7	1,6	1,2	1,4	1,8	1,0	1,[illegible]
CO "	2,2	2,8	1,4	4,1	3,6	4,0	3,9	3,6	3,3	3,4	3,4	2,6	3,8
N_2 "	21,0	12,2	24,7	7,8	16,0	11,8	13,8	9,4	12,4	7,3	13,4	18,0	9,[illegible]
H_2 "	27,2	32,4	28,8	33,3	32,0	31,8	32,0	33,4	34,5	36,6	33,2	31,2	34,[illegible]
C_nH_{2n+2} "	4,4	6,4	3,7	10,0	7,8	11,2	8,4	9,8	8,2	9,3	9,8	8,4	8,[illegible]

x) Aspirator used.

Table 9 a.

Podbielniak distillations of hydrocarbons in uncondensable pyrolysis gas. % by volume of total gas (air-free basis).

	Time for sampling 21.2. 14.3o	28.2. 18.oo
H_2S+CO_2	40,4	38,0
Inert	48,9	49,6
CH_4	5,9	6,8
C_2H_4	2,3	1,3
C_2H_6		1,7
C_3H_6	1,3	1,4
C_3H_8		0,4
i-C_4	0,8	0,2
other C_4		0,8
C_{5+}	0,5	0,4

Table 10.

Analysis of pyrolysis gas.

(calculated to air-free gasis)

Test run nr.	0			1				2			
Date	16.2.			17.2.				18.2.		19.2.	
Time	09.30	16.00 x	01.00 x	10.45	17.00	01.00	01.30	11.15	16.30	00.30	11.00
net W_1, kcal/Nm^3			2550	2940	3240	3370		3140	3630	2680	3330
gross W_u, "			2820	3210	3510	3680		3430	3920	2890	3650
H_2S, % by vol.	1,7	-	1,1	1,5	1,7		1,9	2,2	1,8	1,5	1,2
CO_2 "	40,3	39,9	36,6	38,7	42,5		41,5	40,7	41,8	43,6	40,0
C_nH_{2n} "	3,3	2,3	6,9	3,5	3,4		4,0	3,8	4,0	2,4	4,1
O_2 "	-	-	-	-	-		-	-	-	-	-
CO "	3,8	3,6	2,6	3,1	4,3		3,3	3,6	3,2	4,6	5,2
N_2 "	12,9	11,9	18,9	10,5	4,3		6,0	5,9	5,8	8,5	3,9
H_2 "	29,2	34,2	27,8	34,2	34,5		34,2	34,3	35,7	33,4	34,1
C_nH_{2n+2} "	8,9	8,0	6,2	8,4	9,6		9,1	9,7	11,1	6,0	11,5

x) Aspirator used.

Table 10. (cont.'d)

Analysis of pyrolysis gas.

(calculated to air-free gasis)

Test run nr.	3				4					5
Date	19.2.	20.2.			21.2.				22.2.	
Time	17.15	00.30 x)	10.30 x)	16.00	01.30	11.45	14.30	16.00	01.30	11.00
net W_1, kcal/Nm^3	3040	2710	3060	3020	3000	2700		2790	2900	3020
gross W_u, "	3300	2990	3360	3300	3340	2990		3010	3110	3210
H_2S, % by vol.	1,2	0,2	0,4	2,1	1,0	1,0		1,2	0,6	1,3
CO_2 "	41,5	42,9	43,2	42,5	41,6	40,0	40,4	43,5	37,4	37,2
C_nH_{2n} "	3,3	3,2	3,8	3,3	2,8	3,3	3,5	2,9	3,3	3,9
O_2 "	-	-	-	-	-	-	-	-	-	-
CO "	4,3	5,4	4,4	5,0	5,3	6,3	4,8	5,4	8,5	8,0
N_2 "	9,7	5,5	2,5	4,6	6,3	1,9	9,3	2,1	2,2	3,3
H_2 "	35,1	34,8	36,7	35,8	34,8	39,0	33,4	39,6	39,3	36,0
C_nH_{2n+2} "	5,0	8,4	9,3	7,0	8,3	8,6	7,6	5,8	8,2	9,4

x) Aspirator used.

Table 10. (cont.'d)

Analysis of pyrolysis gas.

(calculated to air-free gasis)

Test run nr.	5					
Date	22.2		23.2	24.2		25.2
Time	16.45	0000	09.15	06.00	17.00 x)	01.30 x)
net W_1, kcal/Nm^3	3140	2620			2240	1610
gross W_u, "	3520	2870			2470	1810
H_2S, % by vol.	1,1	0,8	1,5	1,1	0,7	1,0
CO_2 "	38,3	43,4	45,0	47,0	46,0	43,6
C_nH_{2n} "	3,7	2,2	2,7	1,6	2,0	1,0
O_2 "	-	-	-	-	-	-
CO "	6,0	5,6	5,8	2,6	3,0	1,7
N_2 "	6,8	4,1	6,2	10,6	6,7	13,5
H_2 "	35,3	37,6	30,3	32,1	35,2	34,8
C_nH_{2n+2} "	9,5	6,3	8,6	5,2	7,0	4,5

x) Aspirator used.

Table 10. (cont.'d)

Analysis of pyrolysis gas.

(calculated to air-free basis)

Test run nr.	6									
Date		27.2			28.2				29.2.	
Time	10.00	17.15	23.15	08.30	16.30	18.00	23.30	11.15	17.00	24.00
net W_1, kcal/Nm^3	2750	3020	3040	3080	3510		3270	3120	3480	3390
gross W_u, "	3020	3340	3400	3350	3800		3570	3470	3830	3780
H_2S, % by vol.	1,2	1,1	1,2	2,2	1,5	38,4	1,5	1,9	1,6	1,5
CO_2 "	41,4	38,0	37,2	37,2	40,0		38,7	36,0	38,4	39,7
C_nH_{2n} "	3,8	3,6	4,8	4,6	4,3	4,5	4,9	4,4	4,2	4,5
O_2 "	–	–	–	–	–	–	–	–	–	–
CO "	4,4	4,0	4,4	4,3	3,9	3,5	3,7	3,7	3,2	4,1
N_2 "	3,5	9,4	5,5	8,0	3,7	8,4	2,1	7,2	3,6	3,2
H_2 "	35,1	35,4	35,1	35,0	36,5	36,6	39,4	36,5	38,5	37,8
C_nH_{2n+2} "	10,6	8,6	12,3	9,2	10,7	8,7	10,0	10,8	10,4	9,5

Table 11.

Analysis of fuel gas.

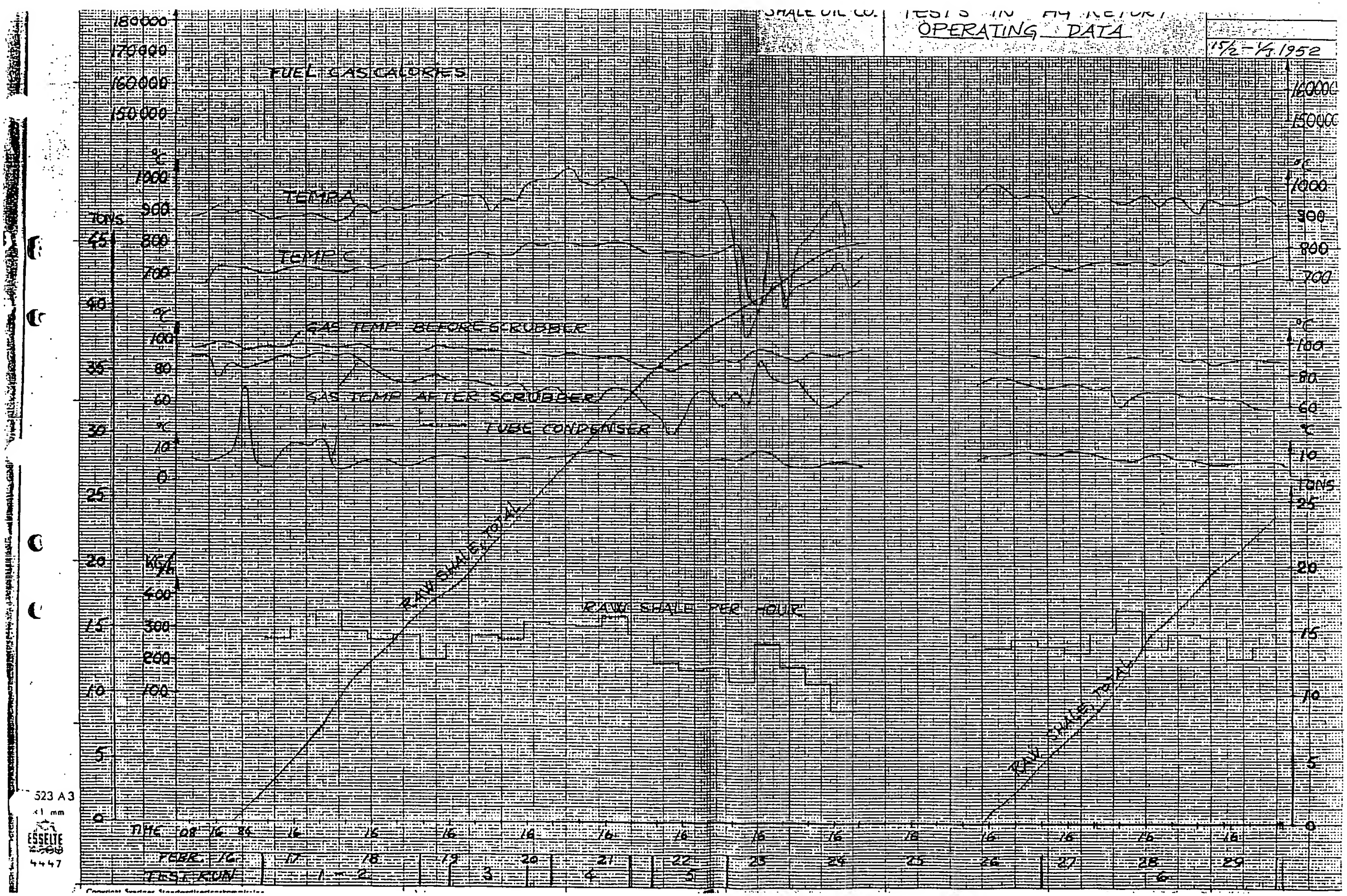
Test run nr.	0				1			2			3		
Date	15.2.		16.2.		17.2.			18.2.			19.2.		
Time	14,00	08.5o	14.3o	00.3o	09.45	18.00	01.00	10.00	17.00	01.3o	10.3o	16.3o	24.00
net W_L, kcal/Nm^3	4150	3760	4175	4000	4040	3920	3860	3740	3800	3920	4160	4190	4140
"	465	[illegible]	470	[illegible]	425	440	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
gross W_u, kcal/Nm^3	4630	4050	4570	4660	4360	4350	4230	4170	4170	4280	4640	4610	4590
"	520	[illegible]	[illegible]	525	493	490	475	470	470	480	520	520	[illegible]
H_2S+CO_2, % by vol.		4,0		3,9									
C_nH_{2n} "		2,4		2,5									
O_2 "		1,0		1,0									
CO "		2,6		2,4									
H_2 "		23,6		19,6									
N_2 "		40,1		38,1									
C_nH_{2n+2} "		26,3		32,5									

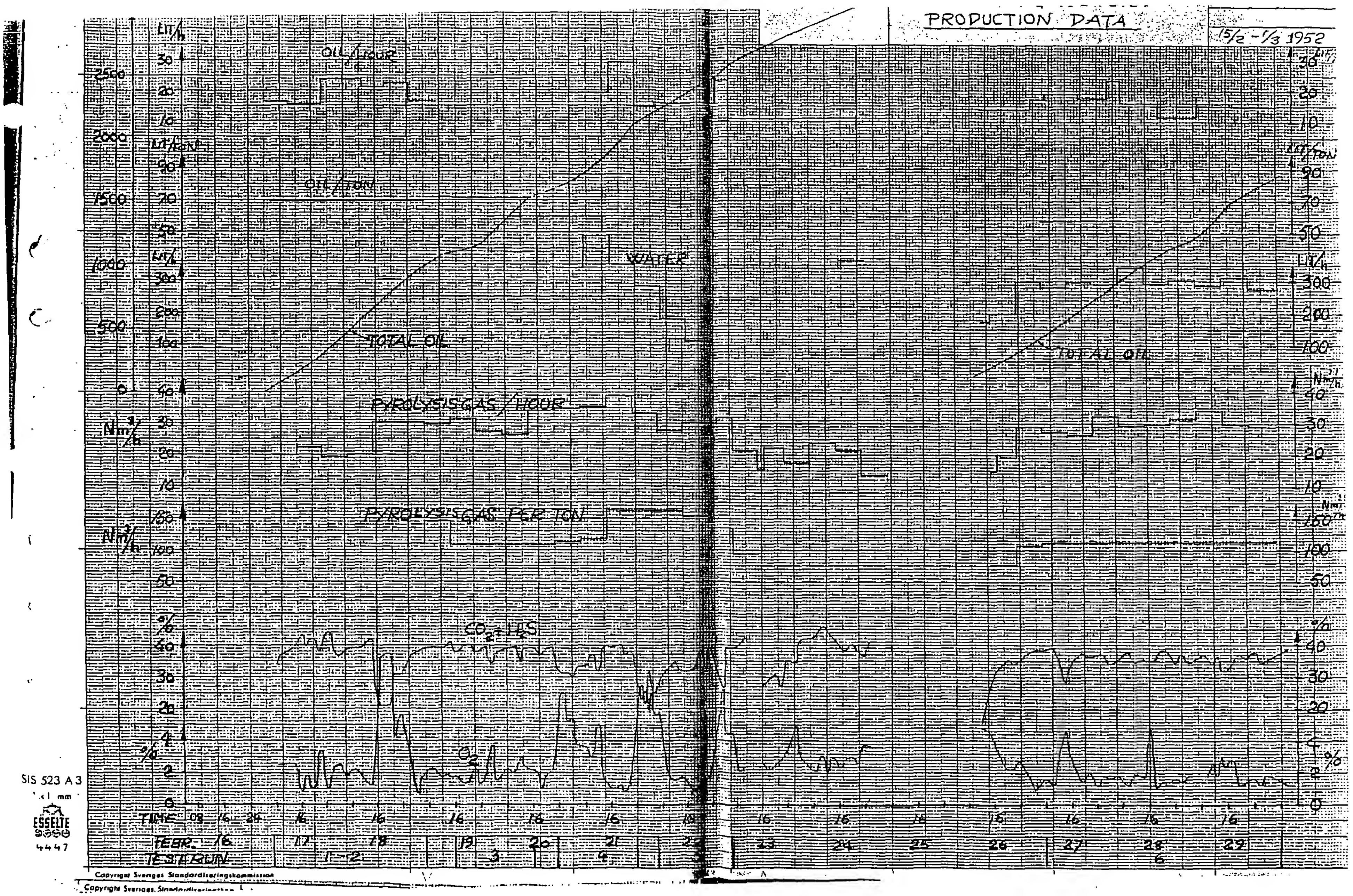
Table 11.

Analysis of fuel gas.

Test run nr.	3			4			5				
Date		20.2			21.2		22.2.	23.2.	24.2.		
Time	11.00	16.00	24.00	10.45	17.00	23.30	16.45	01.00	04.45	16.30	23.30
net W_l, kcal/Nm^3	3840	3910	3240	3520	4060	4020	4420	3980	3560	4210	4530
gross W_u, kcal/Nm^3	4230	4330	3660	3870	4450	4420	5260	4780	3950	4630	5010

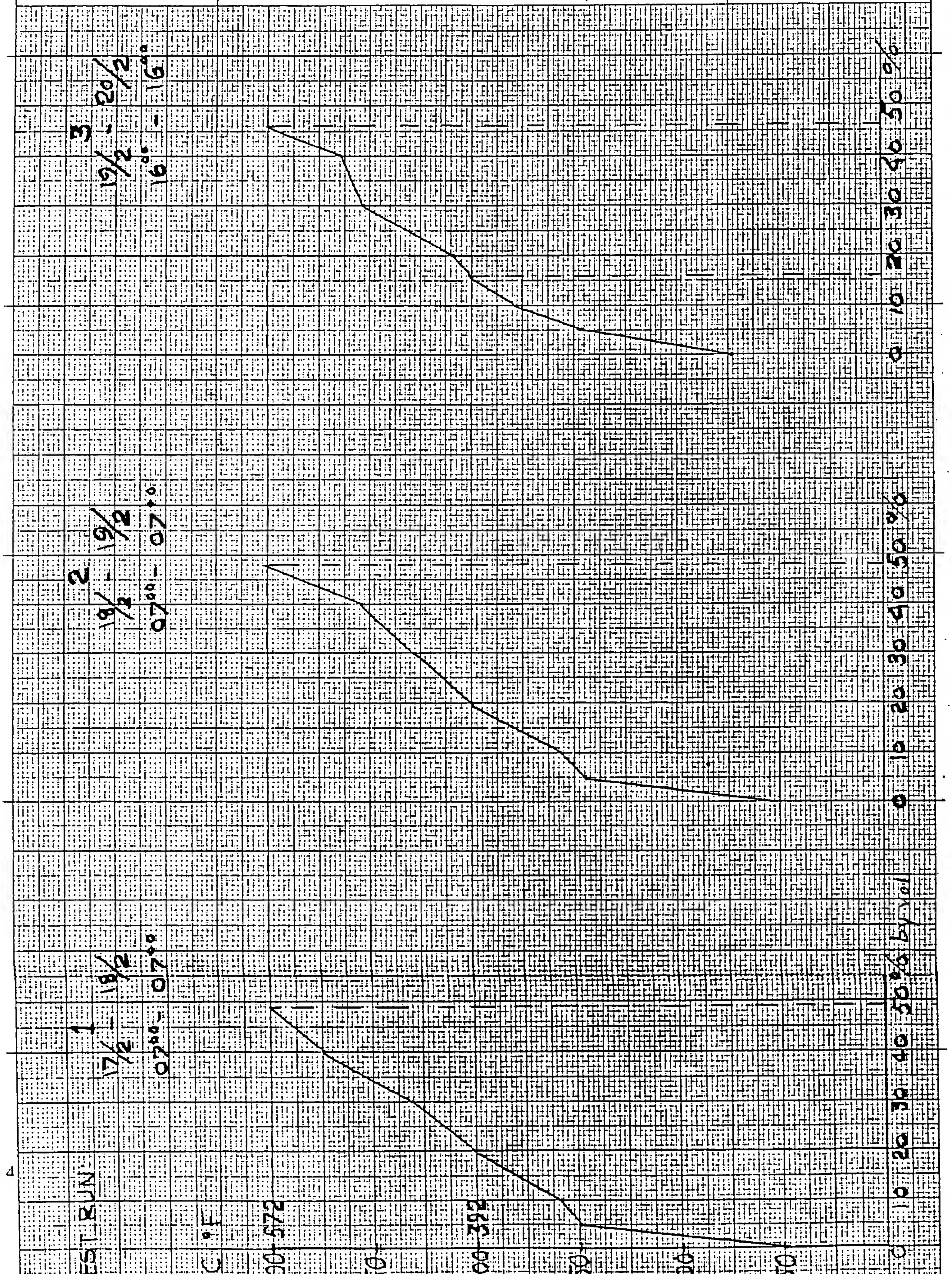
Test run nr.					6				
Date		27.2			28.2		29.2		
Time	08.00	16.30	21.45	07.30	16.00	00.30	09.30	15.30	24.00
net W_l, kcal/Nm^3	3960	4160	4240	4120	4370	4060	3910	4030	3910
gross W_u, "	4320	4600	4670	4520	4800	4470	4330	4440	4320


SHALE OIL CO.
TESTS IN A4 RETORT
OPERATING DATA
15/2 - 1/3 1952
FUEL GAS CALORIES
TEMP. A
TEMP. C
GAS TEMP. BEFORE SCRUBBER
GAS TEMP. AFTER SCRUBBER
TUBE CONDENSER
RAW SHALE TOTAL
RAW SHALE PER HOUR
TONS
°C
KG/h
TIME
FEBR.
TEST RUN
523 A3
ESSELTE
4447

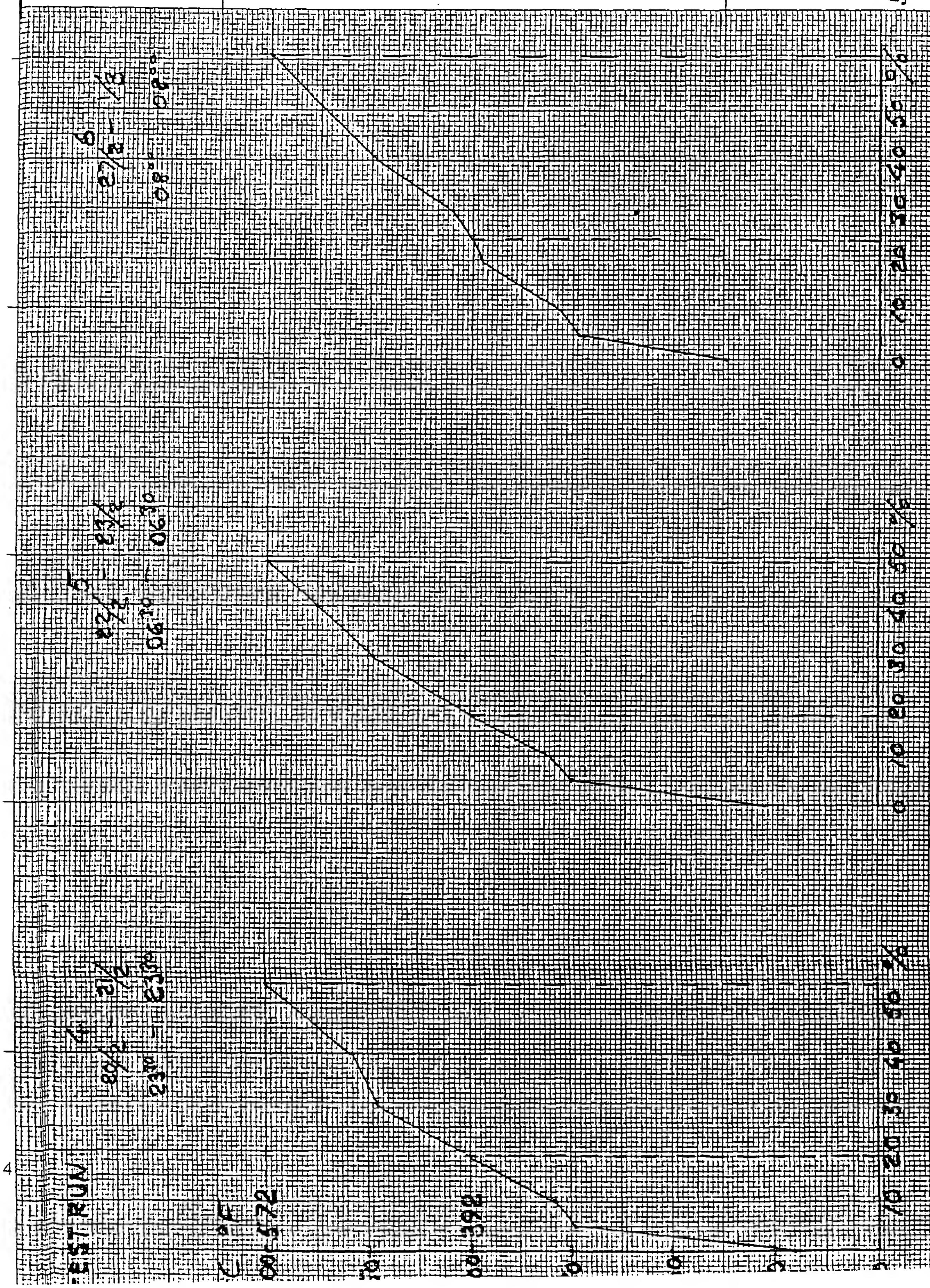

PRODUCTION DATA
15/2 - 1/3 1952
OIL/HOUR
OIL/TON
TOTAL OIL
WATER
PYROLYSISGAS/HOUR
PYROLYSISGAS PER TON
$CO_2 + H_2S$
O_2
TIME
FEBR.
TESTRUN
SIS 523 A3
ESSELTE
4447
Copyright Sveriges Standardiseringskommission

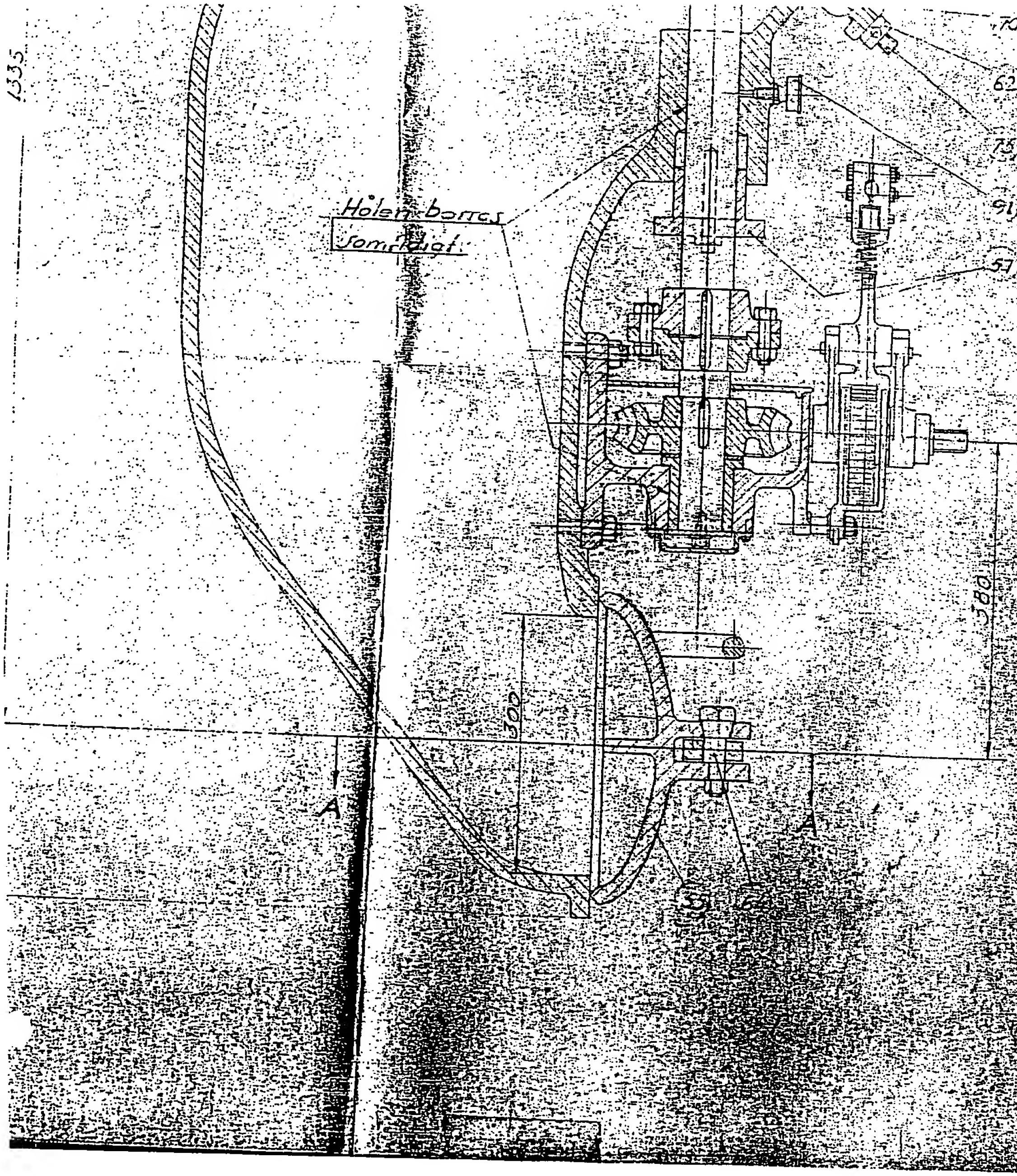
SHALE OIL CO. | TESTS IN HG-RETORT
ASTM - DISTILLATION OF OILS

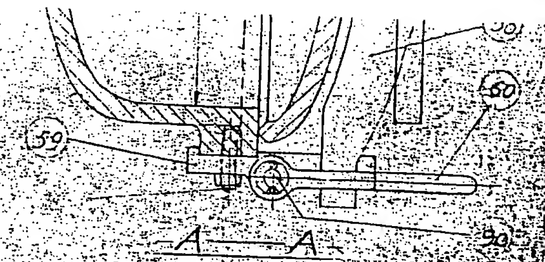
4



SHALE OIL CO. | TESTS IN HG-RETORT
ASTM-DISTILLATION OF OILS







930

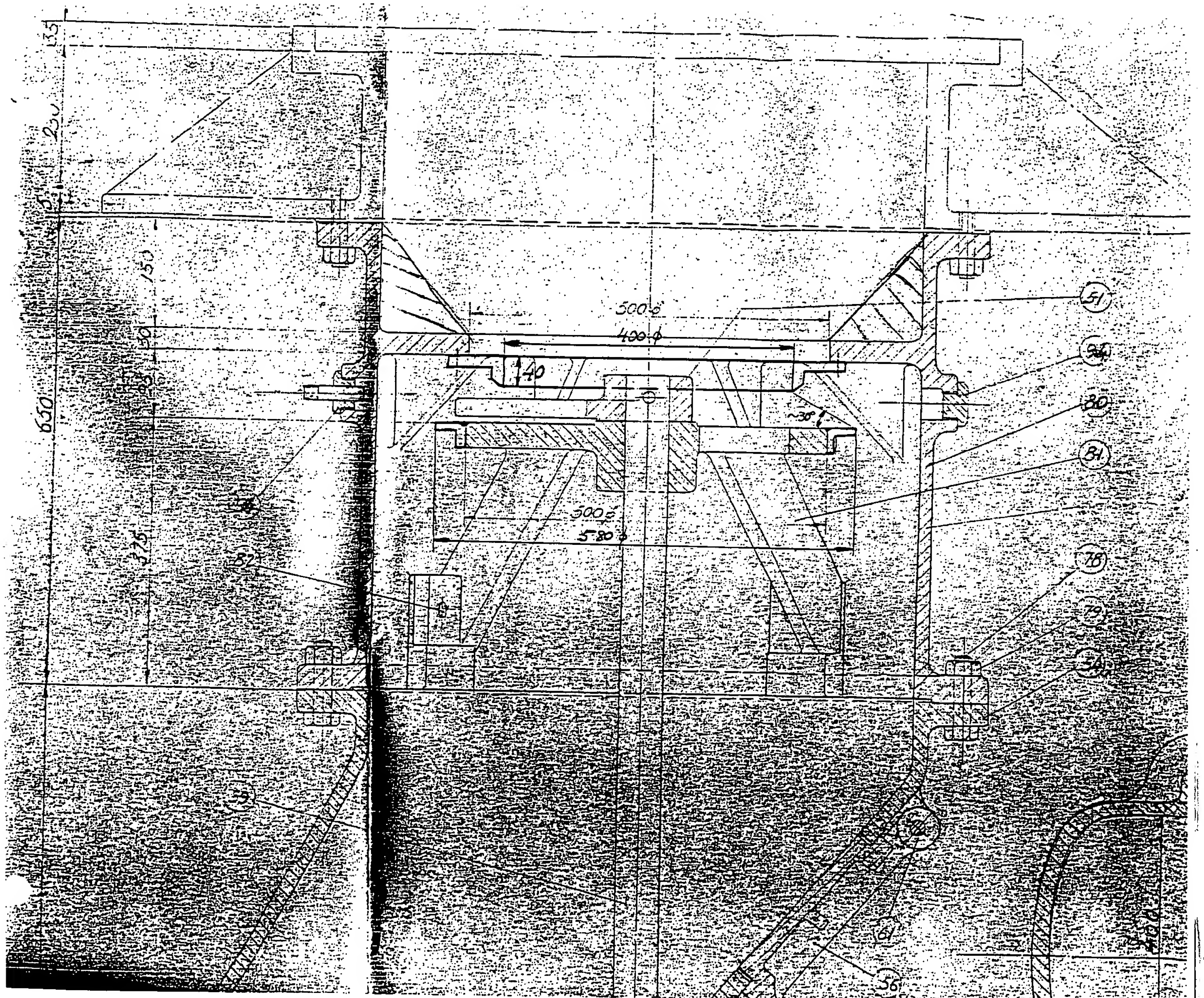
Materialförteckning för ett utförande				
№	Benämning	St.	Material	Anm.
39	Axel	1		[illegible]
51	Utmatningsarm	1		[illegible]
54	Utmatningsbehållare	1		[illegible]
55	Utloppslucka	1		[illegible]
56	Rensslucka	1		[illegible]
57	Packbox	1		[illegible]
58	Bygel	1		[illegible]
59	Fäste till gaffel	1		[illegible]
60	Gaffel för lösurcättning	1		[illegible]
61	Bult	1		[illegible]
62	Låstapp	1		[illegible]
63	Excenterarm	1		[illegible]
64	Excentertapp	1		[illegible]
70	Bult	1		[illegible]
73	D:o BGS-7/8×90	20		[illegible]
79	Mutter BEM-7/8	20		
80	Mellandel	1		[illegible]
81	Tätlock	1		[illegible]
82	Konisk pinne	1		[illegible]
90	Stift	3		
94	Propp 1 1/4" Typ 10 EMS-476	2		[illegible]

930

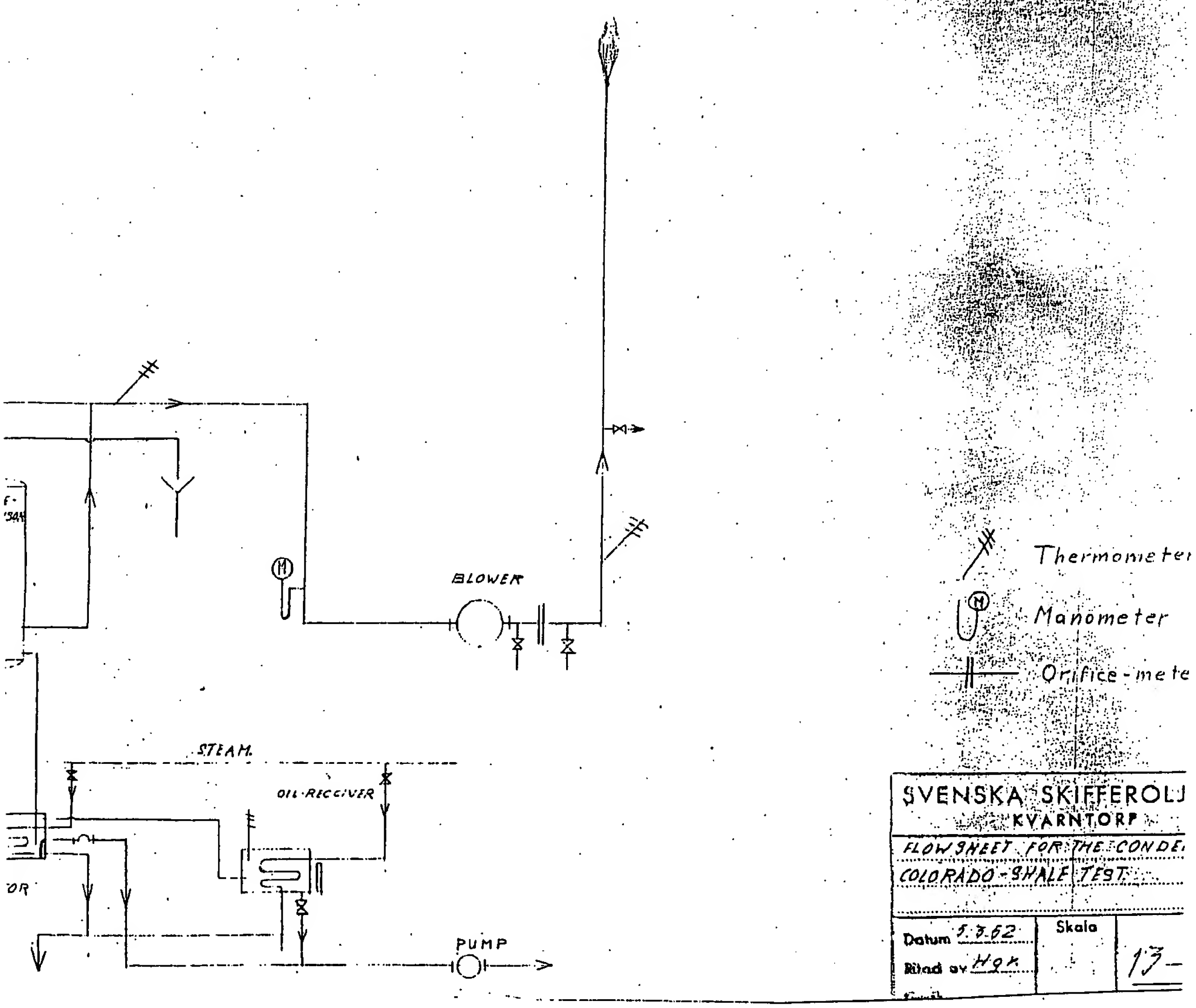
SVENSKA SKIFFEROLJE AB
STOCKHOLM

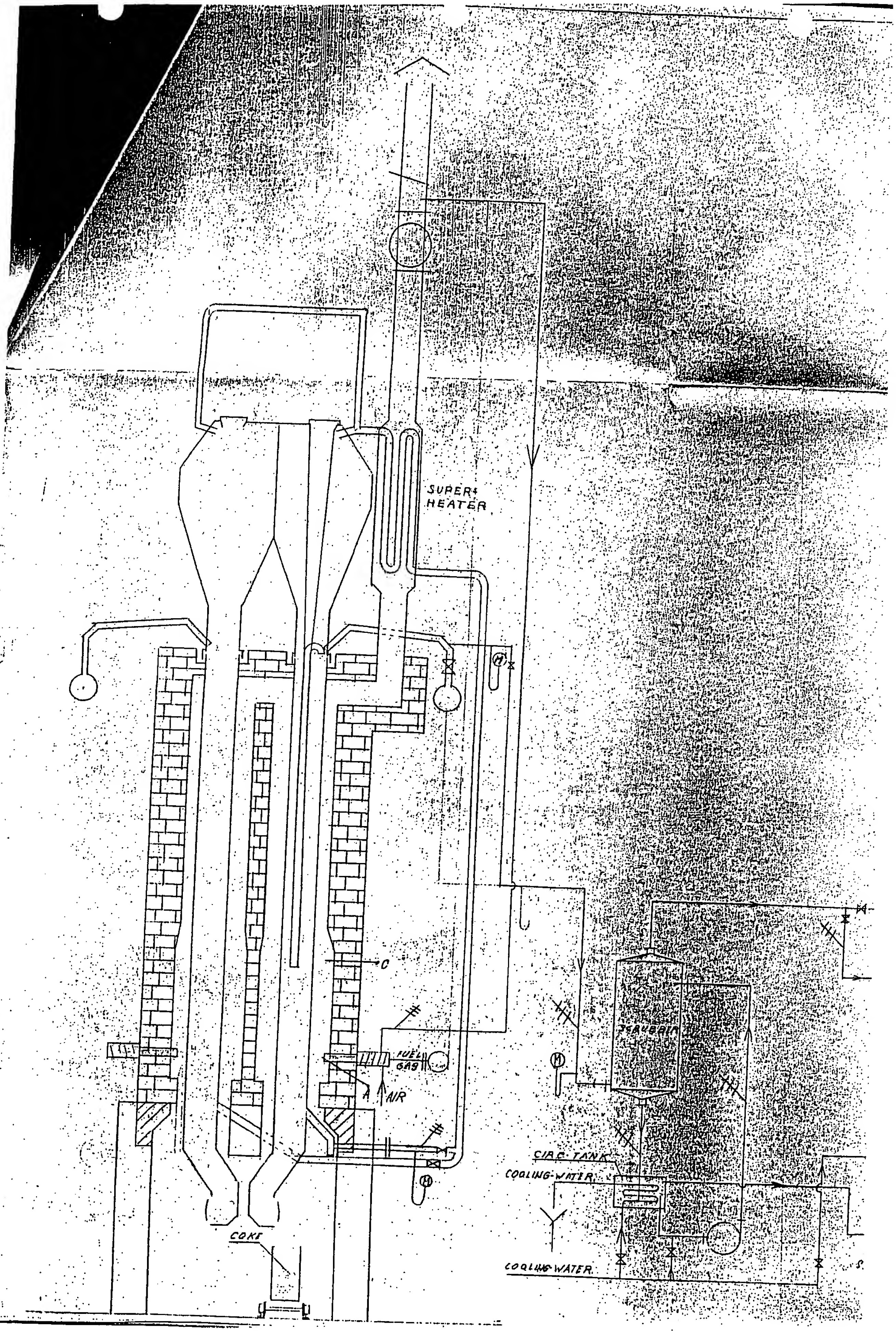
[illegible]

Datum 23-5-47	Skala: 1:5	B-10
Ritad av [illegible]		



500 φ
400 φ
40
~30°
300 φ
580 φ
650
375
150
51
80
81
78
79
61
56


BLOWER
STEAM.
OIL-RECEIVER
PUMP
Thermometer
Manometer
Orifice-mete
SVENSKA SKIFFEROLJ
KVARNTORP
FLOWSHEET FOR THE CONDE
COLORADO-SHALE TEST
Datum 5.3.62
Skala
Ritad av Hgr
13-


SUPER-
HEATER
C
FUEL
GAS
A
AIR
COKE
SCRUBBER
CIRC. TANK
COOLING WATER
COOLING WATER

xxx July 4, 1953.

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
United States Department of the Interior
Bureau of Mines,
Box 792,
R i f l e, Colorado. Airmail

U.S.A.

Dear Mr. Guthrie:

As you already know we have continued the investigations of the Colorado shale in our Bergh-Kvarntorp furnace. We must regret that we only had 20 tons left of this shale and we have come to the conclusion that at least 50 tons still more shale would be necessary in order to fulfill the investigations in such a way that we can rely on the results. However, I herewith send you our laboratory report from the tests with the 20 tons.

If we had the possibilities to continue the test with further 50 tons we think it should be possible for us to determine at least following essential problems:

1) Maximum through-put of shale in our retorts.
2) The yield that is possible to reach when the furnace is running in the best way.
3) After changing the construction of the method to give additional heat to the coke burning bed through non-condensable gases in another way we could find out how to reproduce the advantages really to be reached by using our Kvarntorp-system.

We have very many problems to discuss and I intensively long to meet you personally in order to penetrate our experiences since we met last time at Kvarntorp. I thank you for your kind letter of June 8 with your promise to send your reports "Oil from Coal" and "Oil from Oil Shale".

Mr. Wiborgh left us at the end of June this year in order to start a new company in Gothenburg, Sweden. I presume you will continue your good relations with him so I hope that the next time you visit Sweden we all can meet again and have fine days together.

With my best regards, I remain,

Very truly yours,

Kopia till Prof. Schjånberg,
Dir. Hedbäck,
Ing. Brandberg.

Copy: Mr. Carl Norgren,
Denver.

Colorado

UNITED STATES

DEPARTMENT OF THE INTERIOR

Bureau of Mines

B x 792

Rifle, C lorad

June 8, 1953

Airmail

Mr. Hans Wiborgh
Svenska Skifferolje Aktiebolaget
Kvarntorp
Drottninggaten 3
Örebro, Sweden

Dear Hans:

When I returned to Rifle following a three weeks' absence, I read your letter of May 12 which included a number of interesting items. The fact that you are doing further retorting experimentations on our Green River shale was of particular interest to me. You mentioned that you had processed some of our shale in a recently erected pilot plant. I am wondering if this is a pilot plant designed on the Kvarntorp retorting principle and, if so, what success you have had processing our shale.

As mentioned in the report which I sent you, we feel a process designed for any particular oil shale will not be especially suited for another type of shale unless the two shales are very similar. It is rather strange yet extremely important in retort design that your shale should contain approximately half the oil and yet twice the heating value of our shale. Then, too, the available heat in your spent shale is nine times that of ours. It is quite possible, of course, that modifications of your processe may be adopted for retorting Green River shale. However, I will not go into this matter further until you have received and read the report. We will be interested to know ~~progress~~ of your progress and appreciate your viewpoint on the international shale industry.

Under separate cover I am mailing you a complete set of the 1952 Annual Report of the Secbetary of the Interior consisting of the Summary, Part I - Oil from Coal, and Part II - Oil from Oil Shale. This report was released recently and contains material in which I know you will be interested.

About a month ago a special committee studying appropriations for the Department of Interior suggested to Congress that both the Rifle oil-shale plant and the coal hydrogenation experiment station in Missouri be closed. For about a week our future was very uncertain. However, it now appears reasonably certain that we will receive our funds for at least another year, although the coal hydrogenation plant is being abandoned.

Clar.

Sweden,

May 12, 1953

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
United States Department of the Interior
Bureau of Mines,
Box 792,
R i f l e, Colorado.

U.S.A.

Dear Boyd:

The answer to your letter dated April 24 has been delayed a few days due to a rather extensive traveling the last week.

We thank you for having dispatched a copy of your Report of Special Test conducted here last year. The report is not yet arrived but, when so happens, we will of course study it with care and interest.

Judging from your letter you deem our retorting processes not suitable for processing Green River shale qualities. We resp ct your judgement but feel on the other hand justified to present some general viewpoints pertaining to the tests being made.

The claims earlier made here were fundamentally that the Colorado shale could well be processed in our methods. Moreover, our claims also included the position that the oil derived when distilling your shale with our methods would register a basically different quality as compared with the oil yielded at your quarters.

The first test runs verified our opinion in both instances. The shale did behave itself fairly well in the retorts and the shale crude oil derived was comparable with our oils containing 20 % and above light ends. Personally I think that this figure compares favourably with your produce. This is of course quite natural since we apply indirect heat thereby avoiding combustion of light ends in gaseous state.

On the other hand neither the thermal and general efficiency, nor the heat balances computed did display figures and values to be very proud about. Nonetheless these results cannot be evaluat d independently since they did not aim to give the answer to the final suitability of our retorts. I.e. your shale was processed in one of our commercial retorts not designed and only slightly modified for the purpose of running your material. Commencing the test runs last year we actually anticipated a comparably low efficiency in the first runs and also told this to your witnesses

However, having received a platform from which the general behavi r of your shale may be mput d we hav ventur d int studying the probl m furth r. Th all y of appr aching the pr blems

Dir. Hedbäck.

Colorado

UNITED STATES

DEPARTMENT OF THE INTERIOR

Rifle, Colorado

April 24, 1953

AIRMAIL

Mr. Hans Wiborgh
Svenska Skifferolje Aktiebolaget
Kvarntorp
Drottninggaten 3
Orebro, Sweden

Dear Hans:

Under separate cover I am mailing you a copy of our report on the special tests conducted about a year ago in Kvarntorp. The report, entitled "Report of Special Retorting Tests Using Colorado Oil Shale in the Swedish HG Retort", was prepared by Robert Beverly and presents similar conclusions as brought out in the report by your technicians. In general, it appears that retorting processes designed for handling your shale are not economically applicable for retorting Colorado oil shale because of the large and many differences in the two shales. However, I feel we learned a lot from the tests and have added to our knowledge of oil-shale technology as a result.

We have duplicated the report prepared by your company and distributed it to interested persons within the Bureau, along with Mr. Beverly's report. Mr. Carl Norgren in Denver also has received a copy of our report on the tests.

Recently, I received the information from Professor Schjanberg concerning the shale reserves in Sweden and your recent production figures which I requested through you. The information is just what we wanted and I am sure it will be of use to Mr. Thorne and myself in preparing the literature on oil shale. I appreciate your efforts in this matter.

We expect to start operations on our new Gas-Combustion demonstration retorting plant in six weeks or two months. Calibration and testing of equipment has occupied a good share of our time lately. I shall keep you informed of the results of our early experiments on the unit when we have any information available.

Very truly yours,

Boyd Guthrie
Boyd Guthrie, Chief
Oil-Shal Demonstration Branch

Dir. Hedback

Colorado

UNITED STATES
DEPARTMENT OF THE INTERIOR
Bureau of Mines
Box 792
Rifle, Colorado

March 6, 1953

Air Mail

Mr. Hans Wiborgh
Svenska Skifferolje Aktiebolaget
Kvarntorp
Drottninggaten 3
Örebro, Sweden

Dear Hans:

It was very good to hear from you again and I thoroughly enjoyed your letter of February 24. I am always encouraged in our quest for the furtherance of oil-shale technology when I read of others' keen interest such as you always show.

If you sensed a recession in the interest or development of oil shale here in the U.S., I want to inform you that we are still hard at work on many projects and have made several accomplishments over the past year. Perhaps the publicity on oil shale was not as great this year or it did not reach you.

I was interested in your remarks about oil-shale product markets in Sweden and in Europe. General demands, especially in the petroleum field, in this country are still high because of the continued defense effort, although production is beginning to catch up with the demand in many field.

To bring you up-to-date on our work at Rifle, our new demonstration-size Gas-Combustion retorting plant, which will have a throughput of 200 to 300 tons per day, is now finished. Initial operations are awaiting the completion of several major changes in our raw shale storage and distribution system which were necessitated by the new continuous retorting plant. We hope to start operations of the larger plant within about two months and no doubt we will be busy during ensuing months removing the "bugs" which always show up in a new plant and perfecting operating techniques. By the middle of the summer we should have the plant in steady operation.

Our six-ton-per-day pilot-plant retort has been in continuous operation and recently we completed an extended process variable study. A new pilot plant with a retorting capacity of about 50 tons per day also is being built which will act as a pilot for the demonstration plant, permitting mechanical changes with less expense and time and in which optimum operating conditions can be established for the larger plant.

Colorado.

, Sweden,
October 13, 1952.

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
United States Department of the Interior
Bureau of Mines,
Box 792,
R i f l e, Colorado.
U.S.A.

Dear Boyd:

With your letter dated September 30 we received enclosed the memorandum issued by Mr. G.U. Dinneen to Mr. H.M. Thorne on July 9 this year.

In the first place accept our appreciation for your friendliness to venture into this spectrometer analysis for the purpose of permitting ourselves to compute evaluation data obtained in our laboratories. The memorandum is already submitted to our research department, the department of which is presently engaged in studying and comparing your data together with our material.

We thank you for your favourable communication as regards our report submitted you by Mr. Carl Norgren. Of course, this report could just as well been submitted direct to you but I considered it more correct to funnel the transmission through the so called Colorado-group, which our friend Carl Norgren represents.

It should be noted that the scope of this test with Green River shale was exclusively directed for the purpose of establishing the character of Green River shale oil derived with our type of retorts. We assume this was accomplished since the crude oil received when retorting Green River shale in our retorts contained somewhat 20 % light ends which compares quite favourably with the results received from crude obtained in Rifle.

On the other hand the efficiency of the retorts was comparatively low due to a series of different factors, among them improper size of shale. This efficiency factor, however, was not embedded within the test program as a paramount question. We are, of course, in the same manner as everybody else compelled to attack these problems step by step. And the retort used was one of our commercial unit deployed for the test purpose and not satisfactory for detailed control.

However, we are presently engaged in planning a new test retort based on the experiences evolved when running the Green River shale. It seems like this retort will give an answer to many problems yet unsolved and we hope to take up this matter with you within the near st f w months.

Svenska Entreprenad Akti bolaget
Villagatan 6

STOCKHOLM

Kvarntorp Gejrot/VL 11/8 1952

Härmed be vi få erkänna mottagandet av Edert brev av den 6 augusti 1952, och vi översända samtidigt 1 ex. av vår rapport över prov med Coloradoskiffer.

Laboratorieundersökningen, som utfördes noggrant före de praktiska proven, visad vad vi redan förut voro tämligen övertygade om, nämligen att man icke utan vidare kunde använda den ifrågavarande skiffertypen vid vår Kvarntorpsprocess. Vi voro alltså tvungna att för det praktiska provet tillämpa vår modifierade Rockesholmsmetod. Vi ha i denna retort själva ett synnerligen gott utbyte av olja per ton skiffer. Under den provperiod, som stod till förfogande för Coloradoskiffern, uppnåddes ej genomsnittligt samma goda utbyte, men under vissa provdygn kommo vi i närheten av de genomsnittsvärden, som vi erhålla för vår egen skiffer. Vi hysa inget som helst tvivel om att vi vid kontinuerlig drift skulle komma upp till utbyten på c:a 90 %. Att proven icke visa detta beror dels på den korta provningstiden, som icke medgav de injusteringar, som man naturligtvis måste göra för att komma fram till optimalvärden, dels på att siktanalysen på provpartiet icke var den lämpliga för retorten ifråga. Provskiffern var nämligen nedkrossad för att passa Kvarntorpsugnen.

Provet gav emellertid besked om att den indirekta upphettningen kontra den direkta, som amerikanarna använda, ger en helt annan och förnämligare kvalitet på oljan. Så erhöllo vi sammanlagt c:a 20 - 25 % bensin, mot att amerikanarna knappast erhålla någon eller max. 1 %, och även den tyngre oljan, som vi erhöllo, har säkerligen helt andra och bättre kvalitativa egenskaper än vad den direkta upphettningen ger. Dessutom får man hos oss icke obetydliga mängder icke kondenserbar gas, som håller c:a 3.000 kalorier, alltså en mycket värdefull gas, under det att de icke kondenserbara gaserna vid de amerikanska metoderna äro så gott som värdelösa.

Vi anse emellertid - och detta ha vi klargjort för våra uppdragsgivare i Colorad - att vår Rockesholmsretort icke i oförändrat skick bör komma till användning. Provdriften har emellertid givit oss anvisning på huru vi skola arbeta för att få fram en process, som ekonomiskt bör kunna hävda sig i konkurrens med de amerikanska förfarandena, varvid vi samtidigt skola se till att vi icke riskera de förnämliga kvalitativa resultat vi erhållit. Vi ha sparat c:a 20 ton skiffer, och det är vår avsikt att i slutet av oktober lier början av november i år genomföra prov med d nna kvantitet i en för ändamål t lämpad nykonstruerad ugn, som vi nu uppföra och där vi tagit vara på vunna erfarenhet r i berörda avseenden. Dessa prov draga emell rtid dryga kostnader, och vi skulle ans det vara riktigt, att Coloradointressenterna på ett ller annat sätt bidraga till täckandet av dessa kostnader.

, Sw d n,
August 6, 1952.

Mr. Carl A. Norgren,
3400 South Elati St.,
E n g l e w o o d, Colorado.
U.S.A.

Dear Carl:

In my last letter to you it was mentioned that the reports covering the Green River shale test runs were concluded and subject to various general analysis. We retained the reports here for some time in order to establish a program for our endeavours to present you a constructive proposal for the next phase of evolving the interest in U.S. for shale oil operations.

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When scrutinizing the reports you will find following:

1) The processing of the Green River shale in our retorts is carried out without difficulties, i.e. contrary to suggestions earlier displayed by several specialists interested in other schools and methods.

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3) Due to the specific characteristics of the Green River shale these first test runs carried out were made in the Rockesholm unit. In our earlier correspondence with you the reasons for this routine are explained. However, by processing your shale in this retort a broad base was accomplished for the evaluation of heat balances, throughput and development possibilities.

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5) The crude shale il derived displayed qualities far ab ve the oil received from present retorts used in U.S. This, of course, is quite evident since the principle of "indirect" heating lend itself to better control and better utilization of the products evolved during the pyrolysis. When heating and combusting shale by "direct" heating the bulk of the light ends is actually destroyed. And these products may comprise perhaps the most valuable components inherited in the shale.

6) As displayed in detail in the reports the shale crude oil yielded between 16 - 24 % light products distilled below 392 °F. This compares fairly with the yield of 2 - 4 % received in retorts treating the shale with "direct" heating. The general character of the crude also differs entirely from earlier experience when treating Green River shales. The permanent gases received during the pyrolysis amounted to between 108 - 163 Nm^3 per ton shale; these gases containing several valuable products such as absorption gasoline fractions and propane and butane hydrocarbons. The H_2S concentration in the gas is low, of course due to the low sulphur content of the shale. With sizeable production units the H_2S may nevertheless be utilized for the production of elemental sulphur. The oil also contains paraffin hydrocarbons pointing toward the production of paraffin waxes, a product with in fact a high market value compared to sulphur prices.

No doubt, the crude oil derived from the Green River shale when retorted in our furnaces has a much greater market value than crudes received in other retorts subject to research in U.S. Judging from the average posted price of different crude in No 3 district the value may differ from $ 0,75 to 1,00 per barrel.

7) On the other hand we are definitely not satisfied with the efficiency balances registered during the test runs, values of which being of decisive importance when calculating the general economics of oil shale activities. This somewhat low efficiency record is due to above mentioned conditions of the shale and the retorts as prevailed during the test run phase. Since the retorts were not calibrated for American raw material we were not able to catch all calories that should have been accounted for.

In conclusion we here all feel confident that the problem of exploiting present vast oil resources deposited in U.S. shales will eventually be stimulated by using methods yielding high quality crudes and also introducing possibilities for utilising all components contained in the shale. And this is accomplished by our type of methods, i.e. "indirect" heating processes. This type of methods must, however, be designed and constructed for their specific purpose and the type of shale that is to be treated. The same conditi n exists of course when building a refinery where the units have to b designed from the viewpoint of the crude to be treated.

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P.M.

beträffande besök vid Bureau of Mines anläggning i Rifle, Colorado.

Onsdagen den 9/11 flögo vi till Rifle och mottogos där av Mr. Boyd Guthrie och Mr. Lester Schramm, som omedelbart förde oss med bil till Bureau of Mines försöksanläggning. Man fick redan vid ankomsten en imponerande bild av de skifferfyndigheter, som här förekomma och som säkerligen äro av större dimensioner än någon annan skifferförekomst i världen. Landsvägen gick utefter Coloradofloden och ca 2000 m över vägplanet såg man toppen av bergmassiven, som tämligen lodrätt stupade ned mot dalgången. Mr. Guthrie nämnde, att totala skiffermäktigheten var upp till 800 foot och att skiffern sträckte sig över ett område om ca 650.000 acres. Oljemängden per acres, som kunde utvinnas, räknas till 100.000 barrels, vilket betyder, att man här hade en potentiell tillgång av olja av ca 10 miljarder m^3. Vad detta betyder, förstår man därav, att den sista uppskattningen av Amerikas kända naturliga oljetillgångar rör sig om ca 5 miljarder m^3.

Skifferns oljehalt varierar naturligtvis. Den skiffer, som i dagens läge anses brytvärd, ligger relativt högt upp på sluttningarna. Vi började vår genomgång med ett besök i den försöksgruva, som Bureau of Mines anlagt. Brytningen hade upplagts så, att man lämnade pelare, utgörande 25 % av den area på vilken brytningen företogs. Pelarnas mått voro 60 x 60 ft och hålrummets bredd 60 ft. Takhöjden var ca 37 ft. Brytningen skedde tidigare i tre pallar, men man hade nu övergått till tvåpallsbrytning med en pallhöjd av 37 ft. Man hade lagt ner mycket arbete på att konstruera fram effektiva borrmaskiner. Effektiva borrhastigheten per arbetare var 200 ft/dag. Numera användes uteslutande roterande borrning (tidigare förekom i viss utsträckning stötborrning). Borrningen skedde horisontellt med fyra borrstänger, monterade på samma maskin. Man hade sistlidne februari haft ett allvarligt takras och detta gjorde, att man ställde sig betänksam mot avståndet 60 ft mellan pelarna. Man räknade nog med att i framtiden få lov att minska detta avstånd. Storleken bestämdes i viss mån av att man ville ha svängrum för stora lastmaskiner, som direkt lastade skiffern i truckar. Brytningskostnaderna uppgavs till 30 cents/ton, vilken siffra dock vid senare konferenser korrigerades till 38 cents/ton skiffer, lastad i truck vid gruvans mynning. Allt brutet gods inräknades då såsom fyndigt berg.

Därefter besöktes retortanläggningen. Skiffern krossades i tur och ordning i en vanlig Blakes tuggare, en hammarkross och i en konkross. Allt gods finare än 1/4" avsållades. Den ugnstyp, som konstruerats av Bureau of Mines, den s.k. Gas Combustion Retort, finns beskriven i litt. Det bör observeras, att man vid

konstruktionen gått ut ifrån att så små kvantiteter vatten som möjligt skulle få komma till användning, då man icke har någon möjlighet att skaffa vatten på annat sätt än genom att pumpa upp detsamma från Coloradofloden. För kondenseringen kunde vatten icke komma ifråga. Metoden bygger på att de icke kondenserbara gaserna återföras och förbrännas i retorten tillsammans med skiffern. Pyrolysen sker i en zon ovanför förbränningen och pyrolysprodukterna avsugas upptill. Under passagen genom den kalla skiffern kondenseras oljan. Det är därvid av väsentlig betydelse att de fina dropparna inte flyta samman på skifferbitarnas yta. I stället erhålles hela oljekvantiteten i form av en fin dimma. Dimman slås ned i en rotoklon, varjämte man har en restavskiljning i elektrofilter. Oljeutbytet uppgavs till 95 - 98 % i den lilla försöksanläggningen, som tidigare körts. I den nuvarande anläggningen, som hade en genomsättning av 160 ton/dag, hade man ännu icke uppnått så goda resultat (förmodligen ej mer än 90 %). Kolet i den bildade koksen förbrännes icke, då den utvinnbara kalorimängden är så liten, att man icke vill komplicera processen genom att använda denna del av skifferns värmeinnehåll. Utgående koksens temperatur är under 200°F.

För provraffinering av den producerade skifferoljan hade man ett litet raffinaderi med en Dubbs krackningsanläggning. Oljan, som erhålles ur retorten, är nämligen en mycket tung olja med en besninhält av endast några få %. Den krackade oljan raffinerades med koncentrerad svavelsyra under mycket stora volymsförluster. Det ansågs, att helt andra raffineringsmetoder måste komma till användning om en produktion kommer till stånd.

Hittills har amerikanska staten genom Bureau of Mines lagt ned 14 milj. dollar vid Rifle och därtill 6 milj. dollar vid Laramie, där det mer vetenskapligt lagda studiet av skifferprodukterna ägde rum. För dagen är situationen den, att man i Kongressen överväger huruvida arbetet vid Rifle och Laramie skall fortsätta att hållas i drift eller ej. Man anser, att amerikanska regeringen utfört tillräckligt grundläggande arbete och att det nu ankommer på den privata industrin att ta vid. Man är i USA bestämd motståndare till att staten som sådan skall driva kommersiella anläggningar.

Mr. Guthrie nämnde att, såvitt han kände till, endast Union Oil för närvarande höllo på med skifferforskning. Tidigare hade Standard Oil of New Jersey byggt en försöksanläggning enligt fluid-bed-principen. Man hade emellertid avbrutit försöken då man icke kunde komma till rätta med den höga halten skifferdamm i oljan.

Mr. Guthrie omtalade också, att man från utlandet visat intresse för Bureau of Mines skifferförsök. Mr. José Schor från Brasilien (som även besökt Kvarntorp) har studerat Rifle-anläggningen. Det synes som om man nu äntligen övergivit tanken på bearbetning av den våta Paraiba-skiffern i Brasilien och börjat studera en annan skifferförekomst (Irali ?). Även från Jugoslavien hade en tekniker besökt Rifle. Mr. Guthrie trodde, att man i Jugoslavien på egen hand börjat bygga en gas combustion retort. Vissa ritningar o.d. hade Bureau of Mines ställt till förfogande.

Santa Cruz den 13 november 1955.

Claes Gejrot

Direktör Albin Johansson

Kooperativa Förbundet

STOCKHOLM 15

Sal/DF 5.3.52.

Till svar på Eder förfrågan till Direktör Gejrot av den 2 ds ang. provkörningen med Coloradoskiffern, be vi få meddela, att provkörningen utfördes i slutet av februari med relativt gynnsamt resultat. Vår slutrapport över försöken är under utarbetande och kommer att vara färdig under de närmaste dagarna, då vi omedelbart komma att översända ett exemplar av densamma.

Med utmärkt högaktning
SVENSKA SKIFFEROLJE AB

enl. uppdrag

›RODUCTION

›as Combustion Process Undergoes Tests; ƒ ʾesult in Cheap Oil from Oil Shale

With preliminary engineering and design work al- ›ady under way, a new plant will be in operation next ›ar at Rifle, Col., employing a new and very promis- .g process for the continuous extraction of oil from oil ıale.

Under the supervision of the U. S. Bureau of Mines, ›nstruction has been awarded to Blaw-Knox Construc- ›n Co. Major objectives of the new retorting plant ›e:

To determine cost and yield data that will permit an curate evaluation of the "gas-combustion" process; To provide the technical information that industry eds to design commercial plants; To supply crude shale oil in the quantities required r the Bureau's refining studies.

The new demonstration retort will be patterned after 6-ton-a-day pilot plant which has proved the new ›as-combustion" process both the most efficient and e most economical ever tested at Rifle. Capacity will nge from 150 to 400 tons of oil shale daily. Plant sign will permit a wide range of experimental operat- ›g conditions, and will include all necessary instru- ›ntation for accurate process control and exact ›asurement of results.

The gas-combustion process was developed by the .reau's staff at Rifle during intensive studies made to ›r some simple yet efficient and low-cost continu- .ethod for extracting oil from the immense re- ves of oil shale in northwestern Colorado.

For about six months, now, tests run in the Bureau's ıall pilot plant have revealed good oil recoveries at ›h throughput rates. However, only the new demon- ›tion unit can confirm development research and ›ly it on a scale that will translate theoretical results › concrete facts essential to private industry con- ›ring commercial production.

There are two important features connected with the › process:

It produces and uses as a source of heat for retort- a low B. t. u. gas obtained from the shale and ›ned in the presence of air.

Unlike most other retorting processes, it requires ›her water nor an elaborate system for condensing liquid products that come from the retort in the ›n of mist. (Water, in this semi-desert area, is a ›ce and valuable commodity.)

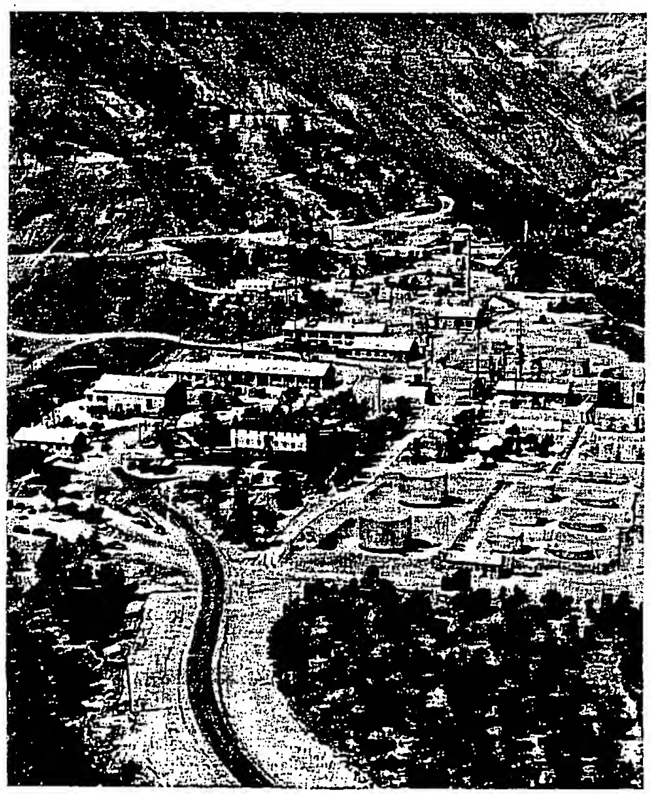
Even more important, investment and operating costs the new process will be substantially lower than ›e for other processes tested by the Bureau, thus in a lowering product costs. Although the grade of de oil obtained by means of the new process will be ›ewhat inferior to average petroleum, finished pro- ›ts of good quality can and will be refined from it.

The system works something like this. Crushed oil fed into the top of the vertical retort and moves downward by gravity against a rising stream of gas. Air is injected near the center of the vessel and the gas burned to provide heat for retorting. As the rising gas from the combustion zone and the downward moving shale pass each other, the shale is heated and the gas is cooled. Upon leaving the retort, the oil-mist-laden gases pass through an oil-collecting system. Part of it is returned to the bottom of the retort where it is pre-heated by spent shale before entering the combustion zone. The large volume of excess gas remaining could be burned to generate heat or power.

There are several further advantages in favor of the gas-combustion retort:

- ► The design is extremely simple, with a minimum of moving parts;
- ► Construction and operating costs are low;
- ► The retort can be easily enlarged for mass-production operations;
- ► It has a higher retorting rate or greater output per unit of area than most other retorts.

During a recent 10-day test run at Rifle, a pilot plant retort using this process achieved a high recovery of liquid oil and demonstrated high capacity. The oil yield averaged 96 percent of the Fisher assay value of the shale treated, and the retort handled 230 pounds



—U. S. Bureau of Mines

OIL-SHALE DEMONSTRATION PLANT set up by the Bureau of Mines near Rifle, Col., includes crushers and B-T-U retorts, at the far end of the processing area. To the right is the refinery and to the left, office and plant service buildings. To the left of the boiler-house's tall smoke stack are pilot plant and laboratory buildings. Tests have been running at this pilot plant for six months and, the process has demonstrated a good oil recovery rate.

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BULLETIN BOARD . . .

Solder——A brochure on the nature, properties and uses of solder has been published by Federated Metals Division, American Smelting and Refining Co., New York, N. Y. Profusely illustrated, the 36-page book has been designed primarily as a reference work for both the layman and the technician.

Machine Tools——A new up-to-date edition of The Cincinnati Milling Machine Co.'s general catalog (No. M-1712) has been released, with new colors and introductory treatment. Cincinnati offers also a completely new, illustrated booklet on its 8-by-18-inch tool and die miller.

Diesels——Several diesel models produced by International Harvester Co. are described in new bulletins just issued by the company: Catalog No. E-51-A covers all six four-cycle power units, ranging from 45 to 180 hp. and capable of powering saw mills, rock crushing plants, hoists, shovels, pumping installations and portable crushing plants; the largest diesel crawler tractor—TD-24—suitable for snaking out heavy logs, laying the largest pipe, coal stripping, highway filling, is covered in Folder E-27-A; Folder E-29-A covers model TD-6, which compacts and loads fill, lays telephone cable, clears and grades building sites.

Motors —— The totally-enclosed, fan-cooled motors produced by Allis-Chalmers are described in a new bulletin (05B7150A), available from the company's Milwaukee, Wis. office. Bulletin covers squirrel-cage, wound-rotor and synchronous types for both horizontal and vertical installation.

of shale an hour for each square foot of bed area. Quality of the oil was comparable in every respect with that from other retorts in which secondary cracking is kept at a minimum.

Highlight: On the basis of the test-run results, a detailed engineering and economic evaluation of the process is now being made. If this evaluation and further tests confirm its indicated merit, the Bureau of Mines will consider building a 300-ton-per-day pilot plant to demonstrate the engineering and economic feasibility of the gas-combustion process for commercial scale operations.

If the considerable investment and product cost reduction indicated by preliminary analysis is combined with other improvements in technique, over-all capital investment for commercial-scale operation of the new process is expected to be at least 25 percent under previous Bureau estimates. Guess is that the new "gas combustion" process may be the answer to the shale oil problem.

RESEARCH

Socony-Vacuum Awards Physics Fell wship

A total of $2,000 was awarded to Brown Univ (Providence, R. I.) by The Socony-Vacuum Oi Inc., for the continuation of a fellowship in physi the coming year.

During the 1951-1952 academic year, Socony-Va will support a total of 20 fellowships at college universities throughout the country, at a total c $40,000.

Continuing the program instituted several yea by the company, recipients of the fellowship a lected by the universities and colleges from stu who have completed at least one year of graduate No restrictions are placed on the recipients by the pany regarding future employment and publicati the results of their investigations. The student free to study subjects other than those connected the petroleum industry. A major portion of the fe ship stipends are paid from Socony-Vacuum to students, to help defray living costs.

Bureau of Mines Studies Beryl Recovery

Beryl, a metal vital to industrial production, i object of a research program now being undertake the Bureau of Mines. At the present time, no prac commercial method exists for recovering minute l crystals.

Mining engineers are now opening up a pegm deposit in the Black Hills of South Dakota for rese purposes (beryl occurs in pegmatite deposits, a with other unusual mineral formations), in an atte to discover some practical way to mine and rec beryl and the other minerals found in pegmatite posits.

Highlight: Beryllium, the metal, is used in the ma facture of x-ray tube windows and as an alloying a with copper. Success in this recovery program wo mean more plentiful and cheaper supplies of this v material for many different phases of industry.

Helium's New Bottle Keeps Cold 100 Days

Only just out of the laboratory, a new vacuum bo is helping scientists and researchers study the beha of matter at super-cold temperatures.

By the use of this bottle, developed at the Westi house Research Laboratories, it is now possible to s helium, the coldest liquid known to man, in liquid fo over long distances. The new bottle keeps helium a temperature 8 degrees above absolute zero for lon than 100 days—a vast improvement over the perfo ance of containers now used.

The new bottle is made of copper in the form o sphere and immersed in liquid nitrogen at 300 degr below zero. To counteract the tremendous pressu which liquid helium builds up when it evaporates tiny opening has been made at the top of the contain Helium is in wide demand by natural scientists eve where, and the fact that it can now be shipped so easi

, Sweden
September 27, 1952.

Mr. John W. Savage
Savage Oil Shale Development Company
P.O. Box 112

D e B e q u e, Colorado

Dear Mr. Savage,

It is quite a long time ago since I got your letter. I deeply regret that I have not written an answer earlier. Many things have occurred since spring. As you know I went to Canada and studied the tar sand deposits. It was very interesting to see these enormous resources and stimulating to plan a development project. I returned from Canada (also passing New York) and have since then been preparing for the field tests, which may be started next year.

In your letter you ask one question concerning the role of hydrogen in the pyrolysis of oil shale. Mr Barlot considers that hydrogen causes a somewhat increased oil yield. As far as we have found there is no effect of hydrogen presence, at least at normal pressures. There are certainly many factors, which can cause similar changes in the oil yields as the 5 - 10 %, observed by Mr. Barlot.

I send you my best wishes and hope we shall meet again.

Sincerely yours,

(Gösta Salomonsson)

, Sw den,
August 6, 1952.

Mr. Carl A. Norgren,
3400 South Elati St.,
Englewood, Colorado.
U.S.A.

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In conclusion we here all feel confident that the problem of exploiting present vast oil resources deposited in U.S. shales will eventually be stimulated by using methods yielding high quality crudes and also introducing possibilities for utilizing all components contained in the shale. And this is accomplished by our type of methods, i.e. "indirect" heating processes. This type of methods must, however, be designed and constructed for their specific purpose and the type of shale that is to be treated. The same condition exists of course when building a refinery where the units have to b designed from the viewpoint of the crude to be treated.

Alr ady last year we reckoned that our ret rts probably had to be modified for th very purpose of processing the Green River shale at a satisfactory and competitiv ffi i ncy rate. The oil derived seems sufficiently good. Wh n n gotiating the test runs last

year we suggested to treat the Green Riv r shale in a Kvarntorp unit and actually commenced er cting a pil t plant. Without knowing the behavior of your shale the prop r design f this pilot plant was not exactly established. Ba d on present xperience and values received from the test runs la t spring we will proceed imm diat ly with the final er ction f mention d pilot plant, the design being modified by the knowledge now receiv d. This plant will be ready for operation in October this year.

With this modified Kvarntorp pilot plant we will process the remaining quantity of the Green River shale still in our possession, some 20 tons. Based on this we will submit you a proposal for the development of an attractive retort especially designed for treating Colorado shale. It may occur that these development costs might be a little high for pure speculative purposes. Therefore, we might both consider whether some cooperative agreement could be drawn where some contribution from your party of interest could be negotiated. Permit me to return to all this in a couple of months when we can judge the results from mentioned test in October.

With the very best regards to you.

Sincerely yours,

SVENSKA SKIFFEROLJE AKTIEBOLAGET

H.C. Wiborgh
Vice President in Charge of Sales

Kopia till Dir. Gejrot,
Prof. Schjånberg,
Dir. Hedbäck,
Öv ring. Salomonsson,
Ing. Brandberg.

SAVAGE OIL SHALE DEVELOPMENT COMPANY
P. O. BOX 112
DE BEQUE, COLORADO

TELEPHONE 6-J

JOHN W. SAVAGE

April 10, 1952

Dr. Gosta Salomonsson
Svenska Skifferolje Aktiebolaget
Drottninggatan 3, Orebro
Sweden

Dear Dr. Salomonsson:

I want to thank you for the very great consideration you gave me during the tests at Kvarntorp. It was a great pleasure to work with you and it was also extremelly informative.

Did you have a pleasant trip? I hope it was and also that it was profitable. I judge by the news reports that it was successful.

I have had the flu since I returned, but all is well now that spring is here.

Enclosed is a copy of a paper by Jean Barlot. I know of no confirmation of his work and there is considerable doubt that it has any validity in respect to Colorado shale. What do you think? However, if it is true concerning some pyrolysis reactions isn't it logical to presume that a hydrogen atmosphere has some effect in the pyrolysis of kerogen.

Please give my best wishes to Prof. Schanberg. I hope he has fully recovered. We were pleased to get copies of his "Fuel" paper and also his paper on "Some Research Problems which have been Studied in Kvarntorp".

I'm sorry you didn't get to Colorado this visit, but I surely hope to see you here in the not to distant future.

My very warmest regards to you and your staff and thank you again.

Sincerely yours,

John W. Savage

2 Encl.

HYDROGENATION OF BITUMINOUS SHALES UNDER ORDINARY PRESSURE

Jean Barlot (1)
Presented by Mr. Delepine

Compt rend 201, 1137-8 (1935)
(Translated by S. S. Tihen, Bureau of Mines, Laramie, Wyoming, September 19, 1947).

The pyrogenation of bituminous shales in an atmosphere of nitrogen, of carbon dioxide or of water vapor transforms a variable quantity of the total organic matter into oil and gas.

This crude oil is a complex mixture in unstable equilibrium and in which condensation and polymerization reactions are produced spontaneously. By fractional distillation one may separate a series of more or less volatile hydrocarbons, and there remains a fixed residue, asphalt, in the proportion of about 25 to 35 per cent of the total quantity of the oil. The liquid part contains on the average about 40 to 60 per cent of unsaturated hydrocarbons; on the other hand, the gas evolved in the course of the pyrogenation contains a notable quantity of free hydrogen, perhaps as much as 40 per cent by weight.

These factors allow one to believe that pyrogenation in the presence of an excess of hydrogen should change considerably the nature of the products obtained. In fact, recent work has established that hydrogenation of certain shales under elevated pressure greatly augments the yield and improves the quality of the products formed (2).

We have had such results, without the addition of a catalyst, and under a pressure essentially equal to atmospheric, when distilling shales of various origins, in pure hydrogen or industrial hydrogen, or in mixtures of carbon dioxide and hydrogen containing at least 60 per cent of the latter. Under these conditions the yield of crude oil is slightly increased (5 to 10 per cent); the condensed products still contain a large proportion of unsaturated hydrocarbons (about 25 to 30 per cent), but upon fractionation they distilled entirely below 360° C. and gave only a small quantity of asphalt (0.5 to 1.5 per cent). The asphalt is a product of inferior value: its nearly total suppression gives a considerable increase in the percentage of the light oils, and thus one may visualize the exploitation of deposits which are at present considered too poor.

The apparatus employed is of the same type as that previously described for making analyses and studies of yields (3). It is composed essentially of one or more steel tubes of 4 cm. diameter and 40 cm. length, heated electrically, or with burners to 500° to 600° C. for two-thirds of their surface. The hydrogen or a mixture of gases rich in hydrogen enters at one end. Condensation is in a flask surrounded with water followed by a Sommelet tube cooled to minus 70° C., or by a gas-oil wash.

It is not necessary to dry the hydrogen nor to purify it before use; also, it is useless to inject super-heated steam, and also the shale may be distributed in the tubes without special precautions.

In a neutral atmosphere, it is necessary to assure the rapid evacuation of the gas and liquids formed to avoid secondary reactions; in a reducing atmosphere, the observation of these conditions has much less importance.

Here are several characteristics of oils obtained from several samples of shales:

	Estonian Kukersite	Autun Shale	Creveney Shale	Chili Shale
Yields of Crude Oil, Percent	23	13	6.5	5
Distilled Between	45°-360°C.	42°-350°C.	40°-330°C.	42°-345°C.
Asphalt Content, Percent	1.5	1.1	0.8	1
Total Sulfur, Percent	0.34	0.18	1.45	0.40
Heating Value (calories)	10,485	10,805	10,685	10,780

The greatest portion of the sulfur is eliminated in the course of pyrogenation as hydrogen sulfide without its producing any appreciable attack on the steel tubes.

---

(1). Meeting of 18th, November 1935.
(2). V. P. Tsuibasov and V. P. Efremov. Fatty Materials, Petroleum and Its Derivatives, No. 323, March 15, 1935, p. 10,443.
(3). J. Barlot. (Bull. soc. chim. de France), 5th series, No. 1, 1934, p. 1014.

Mining.

Senaste på försöksdrift grundade kostnadsuppskattning för skifferbrytning-krossning och -transport (nov. 1950) visar följande:

Direct supervision	0.0113	$/ton
Drilling	0306	
Blasting	0648	
Loading	0209	
Transportation	0527	
Scaling	0101	
Electrical distribution	0212	
Miscellaneous	0252	
∴ Total direct costs	0.2368	
Total costs	0.4263	$/ton[x] (interest on capit. excluded)

Capital investment 247.40 $/ton/day

Depreciation rate per year 11.6 %

Labor percentage of total direct costs 37.7 %

Total daily tonnage 19,200

Labor: Tons per 8-hour man-shift (underground) 165.5

Tons per ——— (total payroll) 99.5

Total number of employees 277

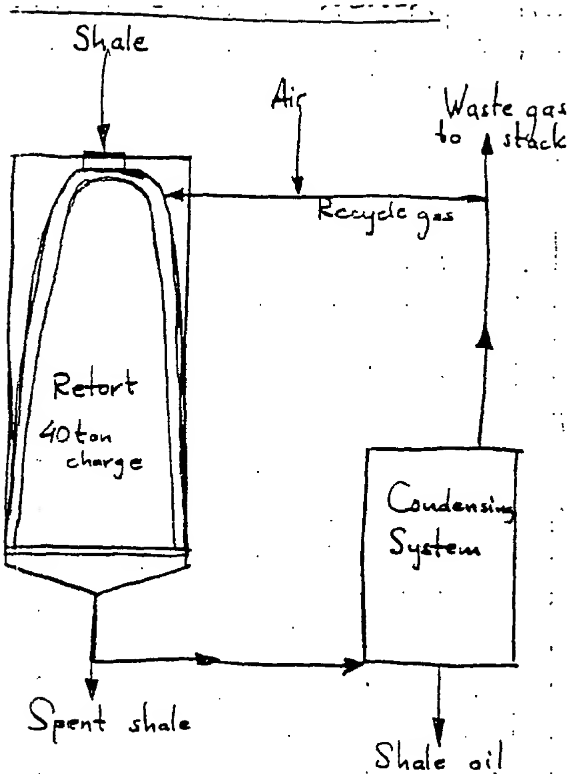
Power etc.: kW-hrs/ton 3.12

Tons broken per pound of explosive 3.1

Tons broken per foot of drill hole 2.8

Gallons of fuels per ton 0.060

Gallons of water per ton 2.7



I en försöksserie ändrades lufthastigheten från 150 s.c.f.m. till 850 s.c.f.m. Oljeutbytet sjönk då från 88 till 67 % av Fi.

En typisk oljeanalys:

Gravity: 22,8 °API = 0.917

Pour point: 85 °F

Viscosity, SUS, 130 °F: 87,4

Init. boil. p.	196 °F
2 %	380
5	421
10	465
20	540
30	598
50	655
70	676

Princip: Retorten satsas med ½"–3½" skiffer, tändes upptill och förbränningszonen får röra sig nedåt, varvid de heta rökgaserna pyrolysera nedanför liggande skiffer. En del av den okondenserbara gasen recirkuleras. Batchwise op. Två dylika retorter prövades i Rifle.

Resultat: Oljedimma, dålig kondensering.x) Någon olja brännes i retorten. Understa skifferlagret i retorten kan ej pyrolyseras. Kanalbildning o. sintringsrisk. 65–90 % av Fischer erhålles allt efter driftförhållandet (air/recycle-ratio etc.).

x) Upp till 11,4 % förlust genom ofullst. kondensering.

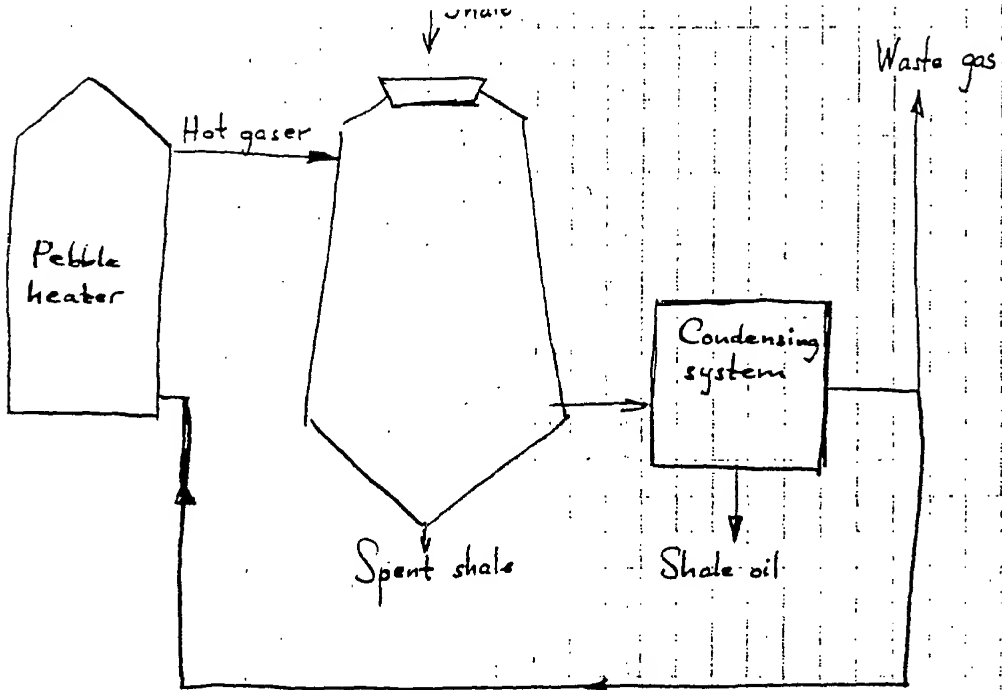
Energibalans:

Ing:	skifferns v.v.	97 %	($218 \cdot 10^6$ BTU/ton)
	Öv. (kompr.-arb. etc.)	3 %	
		100 %	
Utg.	olja	68 %	
	gas (waste)	21 %	
	spent shale	8 %	
	öv.	3 %	
		100 %	

(Värmet för diss. av karbonat är oberäknat i både ing. o. utg. summor.)

Bästa utbytet vid en avverkning av ca.

För en stor-skala-anläggning har man kalkylerat en framst-



Princip: En del av den okondenserbara gasen värmes i en pebble heater och recirkuleras in i retorten. God värmeöverföring och ≥ ca. 100 % utbyte av Fischer. Högre utbyten ju mindre kornstorlek.
Retorten kördes också med överhettad vattenånga i st. f. recycle gas, vilket resulterade i något högre gasutbyte och högre halt av H_2S och CO i gasen.

Operation.	Recycle gas	Superheated steam	
Crude oil gravity	0,933	0,933	
IBP	250 °F	207 °F	
2 %	400	406	
10 %	494	504	
50 %	659	682	
Crude gas: heating value	350	172	BTU/cu.ft.
H_2	27.9 %	28.3 %	
C_nH_m	13,7	6,1	
O_2	—	2,3	
CO	25,5	1,1	
CO_2	11,3	50,3 ?	
H_2S	trace	1,9	
N_2 (diff.)	21,6	10,0	
Spent shale: org. content	2–3 %	1 %	

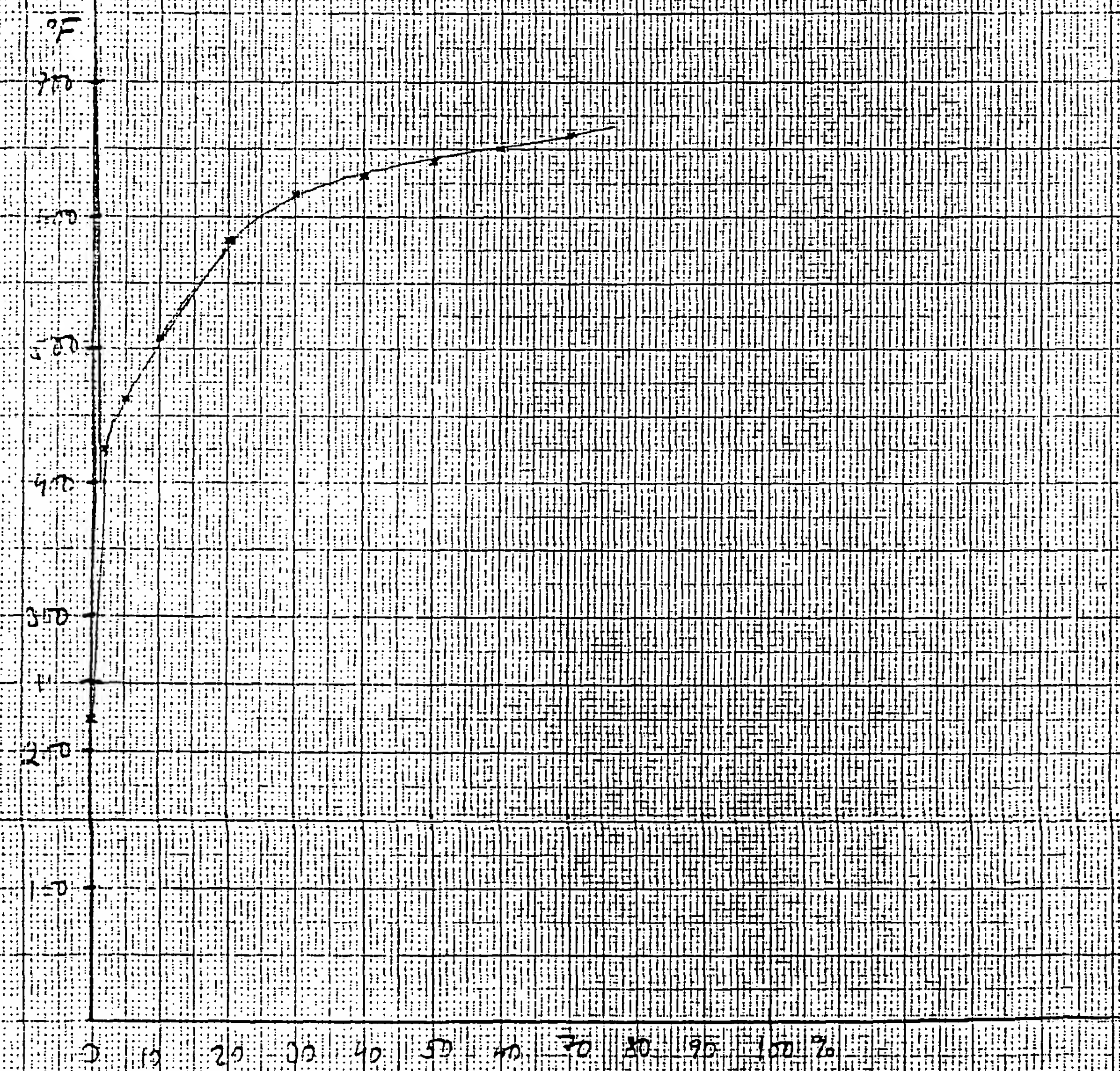
[illegible] of [illegible], B.O.M. Rt. Inv. 4652.

	Low t.	High t.
Fischer assay	21,5	21,5
Residence time	60	40
Temp. retorted shale	915 °F	1020 °F
Oil yield, % of F. a.	107 %	100 %
Gas cuft/ton	833	1277
— " — heating value Btu/cuft	474	340
(Gas × heating value)	395.000	435.000
Crude oil: gravity	17,3 °API	
— " — gasoline content	1 %	

Refining crude shale oil

Process	Charged	Obtained
Atm. distillation	~~[illegible]~~ crude oil 100 %	crude gasoline 6,5 %
Visbreaking	crude oil 100 %	crude gasoline 9,7 %
Recycle cracking	crude oil 100 %	crude gasoline 50,3 % residium 46,2 %
Coking	crude oil 100 %	crude gasoline 13,1 %
Sulphuric acid treatm. + redist.	crude gasoline 100 %	refined gasoline 78,6 %

Distillation curve

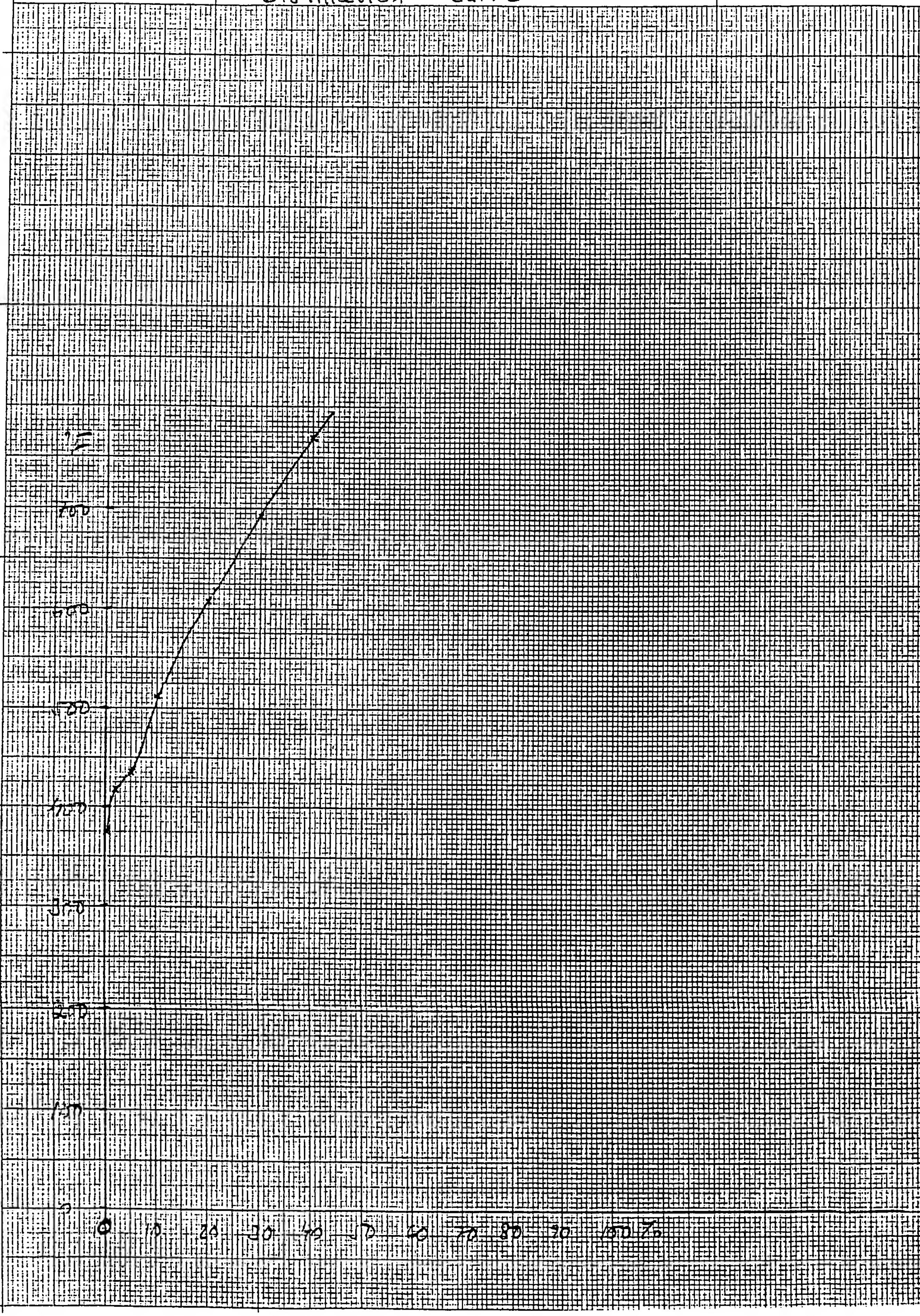


Summary of test run (B.O.M. Rep. Inv. 7[illegible])

Fischer assay	24.0 gals/ton
Oil yield, % of F. a.	96.1 %
Dry gas	5,305 cuft/ton
Crude oil properties:	
Gravity	19.3 °API
	= 0.9383
Gasoline content	1%
Gas properties:	
Gross heating value	83 BTU/cu.ft.
$N_2 + CO_2$	59.2%

Crude oil

Distillation curve



Överlng. Johansson

C.A. NORGREN CO.

December 12, 1951

, Sweden,

January 14, 1952.

Ärende:

MEDDELANDE

Red

Nr

Blad nr

Datum

4/7 1952

Avsändare (avd. + namn + koresp. sign.)

VD/MD

Till

Direktör Wibergh

Jag har här gjort upp ett PM av mera officiell art och ett med mera interna synpunkter, som kanske kan tjäna till underlag för det följebrev, som Du lovat att utarbeta till Colorado-rapporten. Skulle man få fram en positiv linje, så kan jag inte se något annat än att man måste följa de tankegångar jag använt i dessa PM. Huruvida vi skola avisera Colorado-gruppen om de resultat, som erhållits vid arbete med Kongo-skiffern, kan jag j bedöma, men hur som helst ha vi ju åtagit oss att fullfölja försöken med Kongo-skiffern i antydd riktning, och då ligger det ju nära till hands att vi på samma sätt fullfölja proven med Colorado-skiffern.

Om Du anser, att mina synpunkter äro riktiga och kunna tjäna till underlag till följebrevet för Colorado-rapporten, så vore det väl riktigt att sända Svenska Maskinverken, direktör Dahlin, en kopia av PMen. Dahlin är nu hemma.

Hjärtliga hälsningar

tillgivne

000
21

Ankomststämpel

H.C. Wibergh
Vice President in Charge of Sales

Kopia till Mr. Carl Norgren,
Dir. Gejr t, Prof. Schjånberg.

, Sweden,

January 14, 1952.

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
United States Department of the Interior
Bureau of Mines,
Box 792,
R i f l e, Colorado.
U.S.A.

Dear Boyd:

Thank you for your letter of January 5. I note with satisfaction that our sulphur lion arrived without any breakage. Incidentally, this is the only kind of sulphur that the Swedish authorities presently extend export permits for. It is duly noted that your observer, Mr. Robert Beverly, is designed for the mission in Sweden with arrival in Hallsberg about February 1st. We will meet him there and make proper reservation at "Stora Hotellet" in Orebro, your old abode.

Kindly inform Mr. Beverly that we will try to get in touch with him on his arrival in Stockholm where we presume he will stay at "Grand Hotel". We refrain from making any reservation there in order not to interfere with his plans as being drawn in Rifle.

Your kind personal regards to several members of the Kvarntorp family are forwarded.

Yours very truly,

H.G. Wibergh
Vice President in Charge of Sales

Kopia till Mr. Carl Norgren,
Dir. Gejr t, Prof. Schjånberg,

Övering. Johansson

C.A. NORGREN CO.

December 12, 1951

Mr. Hans Wiborgh
Vice President in Charge of Sales
Svenska Skifferolje Aktiebolaget
Drottninggatan 3, Örebro, Sweden

Dear Hans:

I am just in receipt of your letters of the 3rd. Mr. Savage and Mr. Gurthrie have been notified by Mr. Vivian that the test will be run in the latter part of January. Mr. Savage is ready to leave on short notice, and as soon as you have a definite date I am sure it will be taken care of by Mr. Guthrie.

We appreciate, of course, the manifold problems that you have in applying your system to the radically different shale which we sent over. We are all looking forward with much interest to the result of your larger tests.

With very best regards and good wishes to you and your family for a healthy, happy, and prosperous holiday season, I remain

Sincerely,

Carl
Carl A. Norgren

CAN:imb

, Sweden,
December 21, 1951.

Mr. Carl A. Norgren,
222 Santa Fe Drive,
D e n v e r 9, Colorado.
U.S.A.

Dear Carl:

This morning we received your cable dated yesterday reading as follows:

"PLEASE ADVISE DATE FOR START OF TEST
GREETINGS
C A NORGREN CO CARL A NORGREN"

In reply we have already dispatched a telegram establishing the start of the test runs to February 1st 1952 or later in your decision. I am sorry that we have been still somewhat delayed to announce the final time schedule but rebuilding Kvarntorp more or less entirely embeds a heavy stress on everybody, especially our production staff.

In reality we will commence charging the Green River shale in the HG-retort about January 20 in order to check and evolve technical behaviour, heat balances etc. Simultaneously we will establish that condensation and controll apparatus works smoothly. This preliminary test run will be consumated within 6 to 7 days and is expressively decided upon to avoid any delay or hook ups in the large tests which you will witness.

Concluding the preliminary test run we will shut down the retort, cable you before January 26 and await your arrival before commencement of the large runs. I hope this procedure will be accepted by you people since we owe it to you to eliminate any chances of prolonging the actual tests during your visit here by neglecting careful and comprehensive planning. On the other side this will, of course, result in shutting off part of the HG-unit for a considerable time from commercial production but a thorough and comprehensive study of the Green River shale is the primary object when drafting the schedule.

Enclosed please find one copy of this letter for the event y u wish to submit the content to Boyd Guthrie.

Sincerely yours,

SVENSKA SKIFFEROLJE AKTIEBOLAGET

H.C. Wiborgh
Vic President in Charg of Sales

Kopia till Dir. Gejrot,
Prof. Schjånberg,
Övering. Johansson.

, Sweden,
November 9, 1951.

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
U.S. Department of the Interior,
Bureau of Mines,
Box 792,
R i f l e, Colorado.
U.S.A.

Dear Boyd:

Your last letter dated October 22 has been filed on my desk for a few days while I was out of town visiting a few points on the West Coast.

In order to make comprehensive test runs with the comparatively limited material available we have judged it necessary to erect a special pilot plant for test run purposes. Shutting off a battery or a part of a battery in one of our large commercial units and running your shale here might call for larger quantities than we possess.

This pilot plant, incidentally attached to one of the wings of Kvarntorp I furnace, is under construction and will probably b ready within three weeks. Another few weeks might be necessary for trimming in the plant. We will then be in the beginning of December with the holidays ahead.

Therefore, we suggest that the test runs should take place around the middle of January if this would suit you or Mr. Beverly. Within three weeks we will be able to transmit you a detailed schedule of the test runs pending. I hope this will cover your question.

One of the members of the so-called Colorado-group, Mr. Frank H. Ricketson, Jr., visited us yesterday and went through our works. He was a very nice gentleman and we had a very interesting conversation while demonstrating Kvarntorp. I told him that we all here certainly would appreciate you visiting us in connection with the test runs and I would not be surprised if he contacted you when returning home to Denver.

Sincerely yours,

Copy: Mr. Carl Norgren,
Denver.
Dir. Gejrot, Prof. Schjånberg,
Övering. Johansson.

Prof. Schjanberg,
Öv ring. Johansson,
Ing. Salomonsson.

UNITED STATES

DEPARTMENT OF THE INTERIOR

Bureau of Mines

Box 792

Rifle, Colorado

January 23, 1952

Air Mail

Mr. Hans Wiborgh
Svenska Skifferolje Aktiebolaget
Kvarntorp
Drottninggatan 3
Orebro, Sweden

Dear Hans:

This will acknowledge receipt of your cable of January 19 advising that the starting of the final run has been postponed and that our engineer should arrive February 18. I have been awaiting receipt of the letter mentioned in your cable but since it has not arrived, I thought I had better advise you immediately that Mr. Beverly's arrival time at Orebro has been postponed two weeks. He will now arrive in Hallsberg on the afternoon of February 15 rather than February 1.

We had been advised by Mr. Norgren that your research test runs were scheduled to start January 21 and that any time after February 1 you would be in a position to conduct the test for our observer to witness. Thus, because of this advice we arranged the original schedule for Mr. Beverly. I sincerely hope that the test can now be started February 18 as Mr. Beverly has several other commitments in Europe and it is very difficult to make any additional rearrangements of his schedule. When you receive my letter of January 17, be advised that Mr. Beverly will arrive in Hallsberg via Oslo rather than Stockholm. He is scheduled to arrive in Oslo February 14 and spend that night at the Grand Hotel.

Upon receipt of your cable postponing the tests, I contacted Mr. John Savage and he advised me that he would change his reservations so that he would arrive in Hallsberg on February 15. I believe it is his intention to come to Hallsberg from Copenhagen. No doubt he will keep you informed as to his plans.

With kindest personal regards,

Yours truly,

Boyd Guthrie
BOYD GUTHRIE, Chief
Oil-Shale Demonstration Branch

Sweden,
December 5, 1951.

Mr. Carl A. Norgren,
222 Santa Fe Drive,
D e n v e r 9, Colorado.
U.S.A.

Dear Carl:

Thank you for your last letter dated November 27 with a few clippings covering the U.S. synthetic fuel production program. The articles were very interesting.

Last Monday we had a staff meeting regarding the development work carried out with the Green River shale. The meeting was attended by Claes Gejrot, Ed. Schjånberg, Arvid Johansson, myself and the project manager in charge of the development work, Dr. G. Salomonsson. A synposium follows:

1) The laboratory tests mainly verify the properties of the shale as presented in the Bureau of Mines literature; with two fundamental exceptions. In the first place the light ends from distillation, i.e. the fractions below 200°C, amount in our analysis to approximately 20 % against only a few percent given in the literature. We use, of course, an entirely different retorting method compared to the methods used in U.S.A. In the second place the distilled shale, the coke, seems only to contain about 100 kcal/kg, a figure considerably lower than that earlier suggested.

2) Since the basic principle of our retorting methods embraces a strict separation between distillation gases and combustion gases we work with an entirely different heat balance than that applied when treating the shale in, for example, a gas combustion retort. The distillation gases and other organic substances burnt in this retort we aim to utilize for the manufacture of light gasoline, propane, butane etc.

3) Due to this somewhat different heat balance equation we work with together with the low calorific value of the coke exhibited, the Kvarntorp retort need to be subject to a series of m difications, the w rk of which will embrace considerable and tim demanding research. Therefore, we aim to approach a somewhat m dified alley of scrutinization.

4) We will run the Green River shal through on f our HG-retorts shut off and supplied with separate condensation f r the purpos . This line of procedure will giv us the same basic results as earlier assumed with the Kvarntorp method and will sh rt cut the final valuation of U.S. shale in Swedish retorting systems.

5) The test runs in the HG-retort will take place in the third or fourth week in January 1952 if this time is convenient for your observers. We will have another staff meeting on December 11th when details and exact dates of the test will be scheduled. On December 12th I will dispatch this schedule direct to you.

6) At this time the work would hardly benefit by releasing any report of the laboratory work concluded. This will all be compiled when the final test runs are concluded.

I should appreciate it very much if you would care of taking up above mentioned line of action with the Bureau of Mines people and present us your opinion. A copy of this letter is enclosed if you would prefer to give it to Boyd Guthrie.

With the best regards to all of you, I remain,

Sincerely yours,

SVENSKA SKIFFEROLJE-AKTIEBOLAGET

H.U. Wiborgh
Vice President in Charge of Sales

Kopia till Dir ktör Gejr t,
Prof. S hjånberg,
Övering. Johansson.

, Sweden,
January 29, 1952.

Mr. Carl A. Norgren,
3400 South Elati St.,
E n g l e w o o d, Colorado.
U.S.A.

Dear Carl:

1. Today I received a letter from Boyd Guthrie dated January 23. Since I do not know whether you have received a copy one is enclosed for your knowledge.

Everything is now arranged for the test runs to start February 18. Mr. John Savage will also witness the test runs as mentioned by Boyd Guthrie in his letter and also in an earlier letter direct from him.

Just for the case of formality we should like to have your verification that Mr. Savage acts as your observer and that he is your trustee and will not misuse his mission as your man. In fact, we have earlier talked about Mr. Savage but no formal authorization has been extended by you or your group. He is naturally very welcome but we like to have all things straight when starting the tests.

With kindest personal regards,

Sincerely yours,

H.G. Wiborgh
Vice President in Charge of Sales

Kopia till Dir. G jr t,
Prof. Schjänberg,
Övering. Johansson.
Ing. Salomonsson.

, Swed n,
January 19, 1952.

Mr. Carl A. Norgren,
3400 South Elati St.,
E n g l e w o o d, Colorado.
U.S.A.

Dear Carl:

In my letter of January 14 I wrote to Mr. Boyd Guthrie under his address in Rifle about Mr. Robert Beverly appointed to witness our test runs with the Green River shale. Mr. Guthrie told me that Mr. Beverly would arrive to us around February 1st.

This morning we had a staff meeting going through the tests pending and the preliminary time schedule pinpointed for the project. Due to several reasons, among them a nasty snow storm during the last week, the reconstruction of the HG-retort set aside for the purpose has been somewhat delayed. The retort will now be ready for preliminary runs around February 1st and Professor Schjånberg and Mr. Johansson need a week or so to trim the retort and accessory installations first with Swedish shale and afterwards with a small quantity of Green River shale.

Therefore, we should be indebted to you if Mr. Beverly would adjourn his visit to February 18 when everything will be ready for him. Of course, we regret this delay but are anxious to have everything settled when he arrives avoiding any unnecessary unproductive days during his visit.

In order to immediately announce this proposition I dispatched today following cable both to you and Mr. Guthrie:

"SEMICOMMERCIAL TEST RUNS COMMENCING FOR
GENERAL ANALYSIS OWN RESEARCH ABOUT FEBRUARY
FIRST SUGGEST YOUR SPECIALIST TO WITNESS
FINAL RUNS ARRIVE HERE FEBRUARY EIGHTEENTH
LETTER FOLLOWS GREETINGS WIBORGH

SVESKIAB"

A copy of this letter is for the sake of convenience also sent by air mail to Rifle.

Kindly inform us about your opinion regarding the new date of test commencement. Of course, we can ac elerat things a few

days if needed but both our research and production departm nt have presently so many other programs t conclude that I personally have refrained from rushing them too much.

Sincerely yours,

H.C. Wiborgh
Vice President in Charge of Sales

Kopia till Boyd Guthrie,
Direktör Gejrot,
Professor Schjånberg,
Överingeniör Johansson.

, Sw den,
January 29, 1952.

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
United States Department of the Interior
Bureau of Mines,
Box 792,
R i f l e, Colorado.
U.S.A.

Dear Boyd:

Today I received with thanks your letter of January 23 and have already filed your earlier letter dated January 17 regarding Mr. Beverly's Swedish itinerary. Following is noted.

1) Mr. Beverly will arrive in Hallsberg on the afternoon Friday February 15. Since there are several train connections between Oslo and Hallsberg kindly ask Mr. Beverly to send us a cable from Oslo stating which train he arrives on.

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All here are naturally sorry that you could not arrange to come over yourself. However, as it is intended these pending test runs will probably be followed by several discussions and negotiations and then I hope we meet in person again.

With kindest personal regards,

Sine rely yours,

H.C. Wibergh
Vi e Presid nt in Charge of Sales

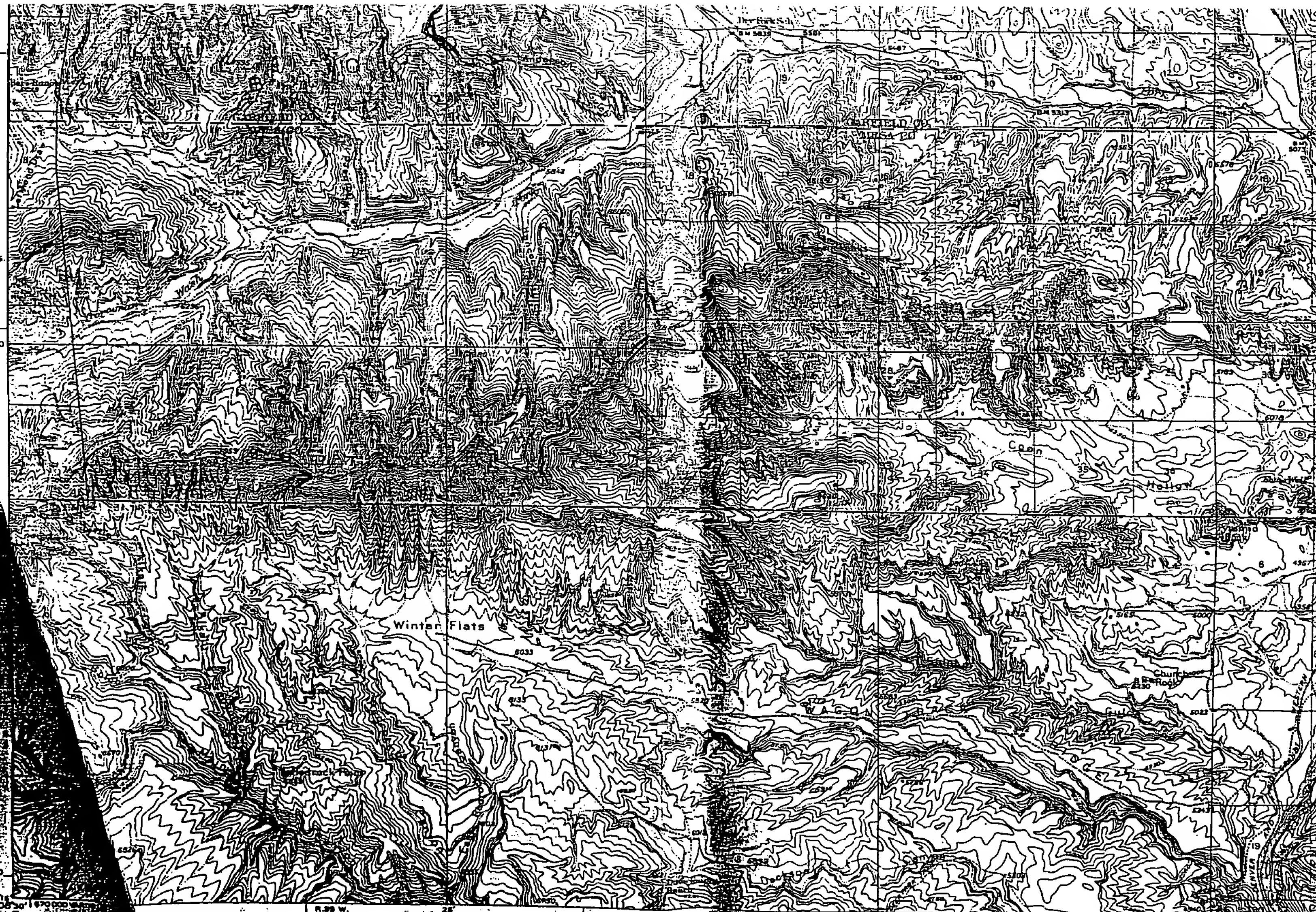
pia till Dir. Gejrot,
Prof. Schjänb rg,
Övering. Johansson
Ing. Salom nsson.

Copy to: Mr. Carl A. Norgren.

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SCHOOL OF MINES
M.F. COOLBAUGH, PRESIDENT

COLORADO
ROAN CREEK QUADRANGLE



Topography by ... issner and W. J. Lloyd
and from De Beque ... map
Control by U. S. Geo... Survey
Surveyed in 1926

Polyconic projection. North American datum
5000 yard grid based upon U.S. zone system, E

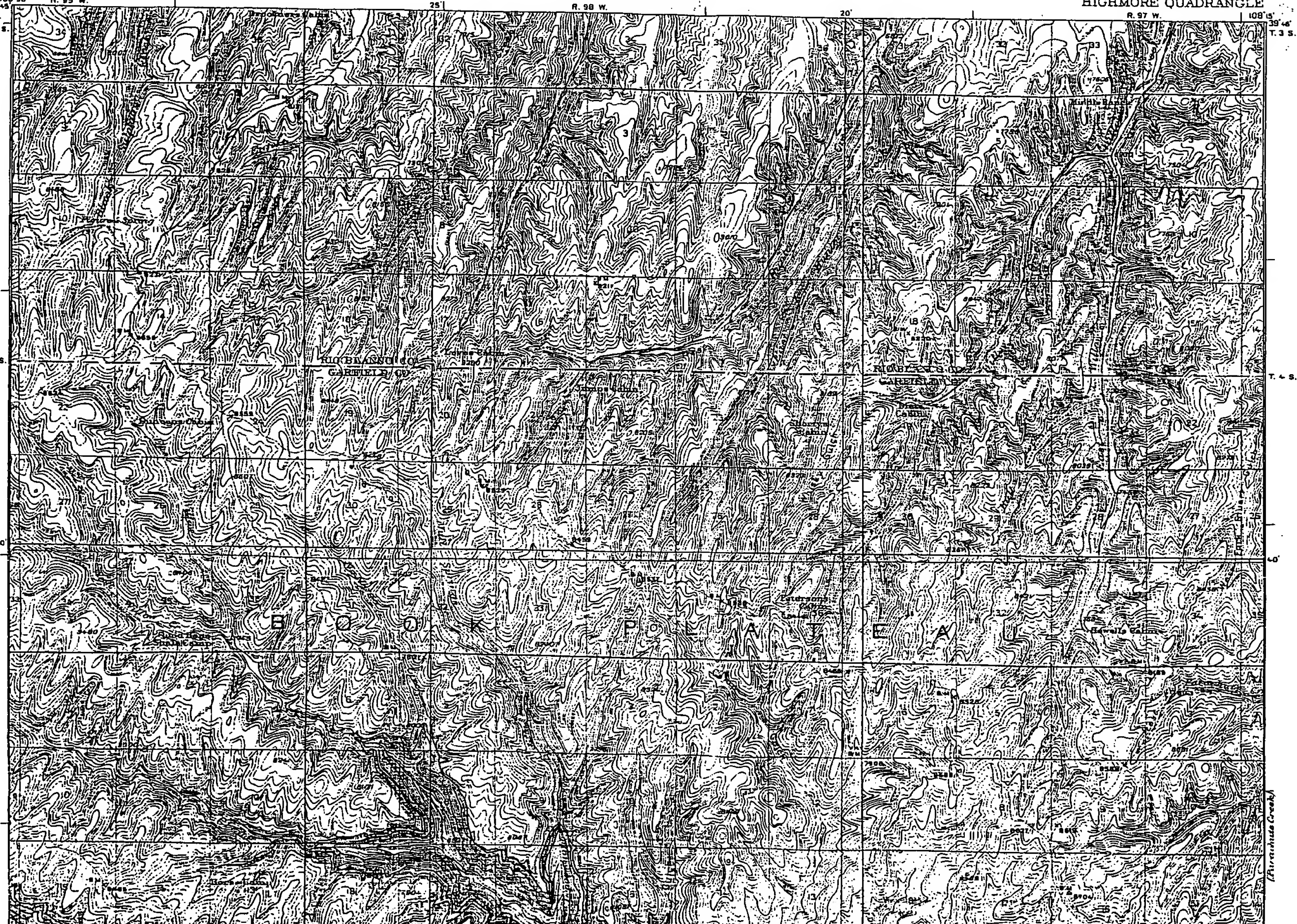
Land lines pertaining to T. 8 S. of R. 99 W. and T. 9 S. of Rs. 99 and 100 W. and part of T. 9 S. of R. 98 W. are omitted because land plats and topography cannot be reconciled

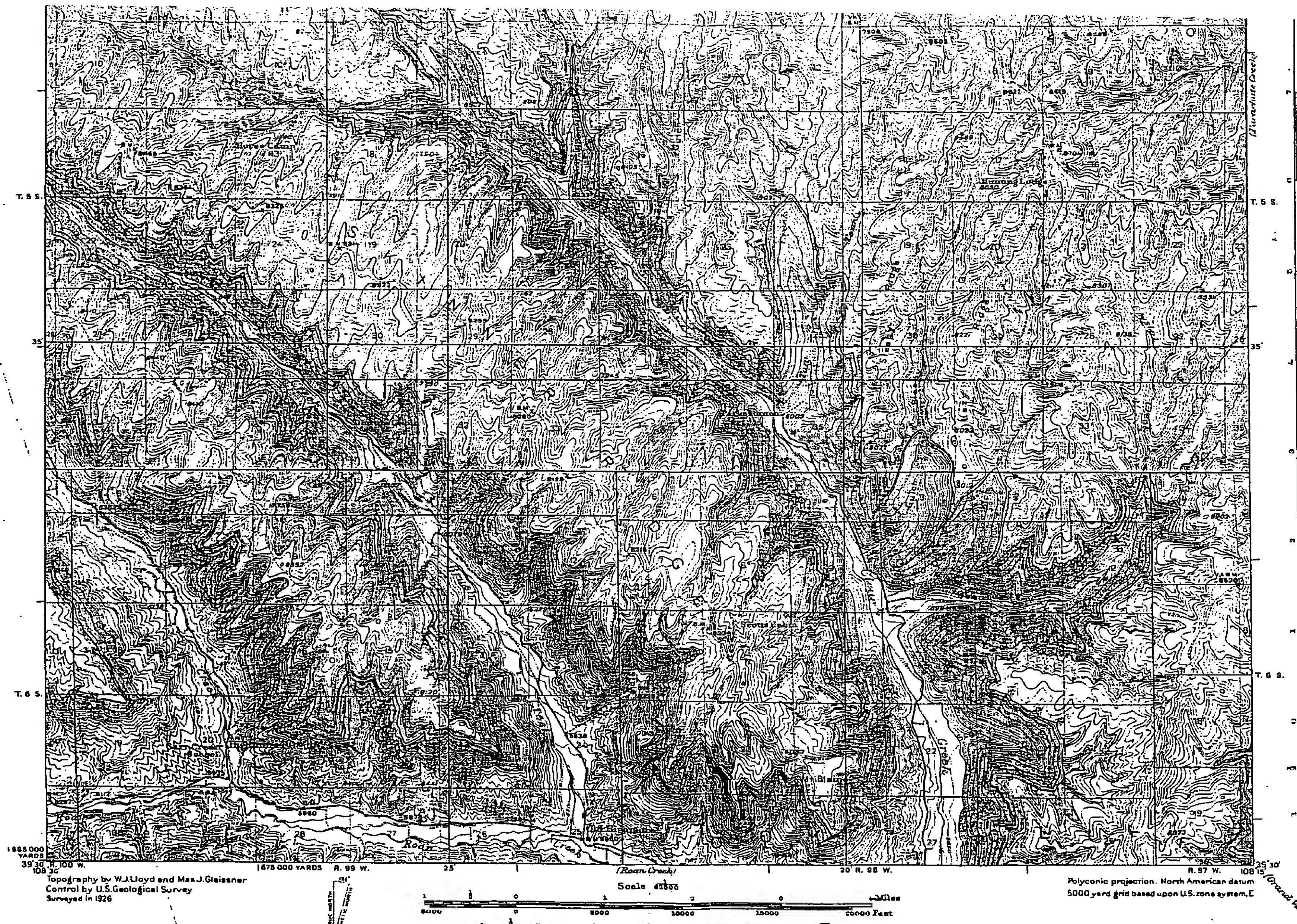
ROAN CREEK, COLO.
Edition of 1929

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

STATE OF COLORADO
CLARENCE J. MORLEY, GOVERNOR
SCHOOL OF MINES
M.F. COOLBAUGH, PRESIDENT

COLORADO
HIGHMORE QUADRANGLE





Topography by W.J.Lloyd and Max J.Gleissner
Control by U.S.Geological Survey
Surveyed in 1926

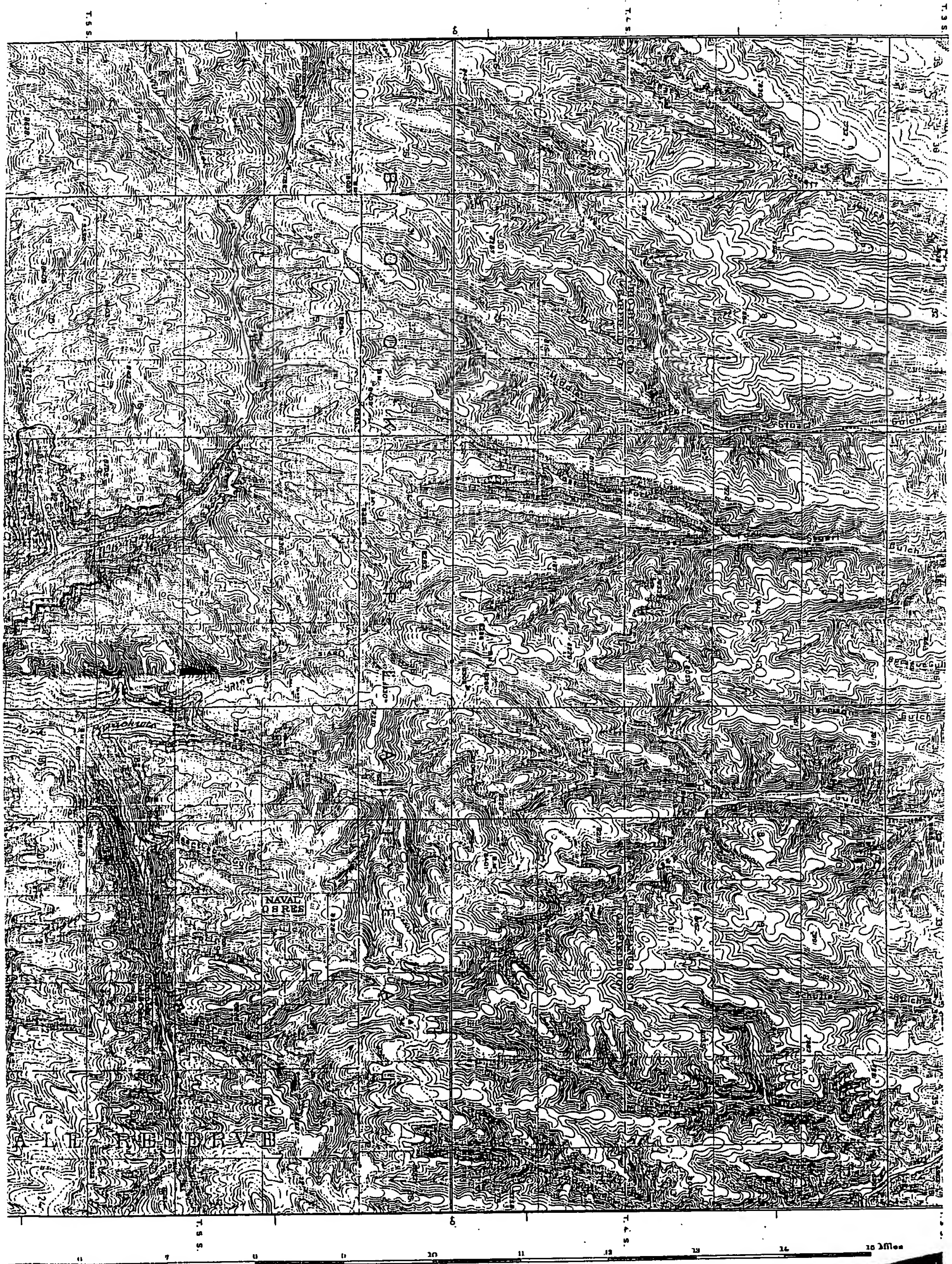
APPROXIMATE MEAN DECLINATION, 1926

Scale $\frac{1}{62500}$

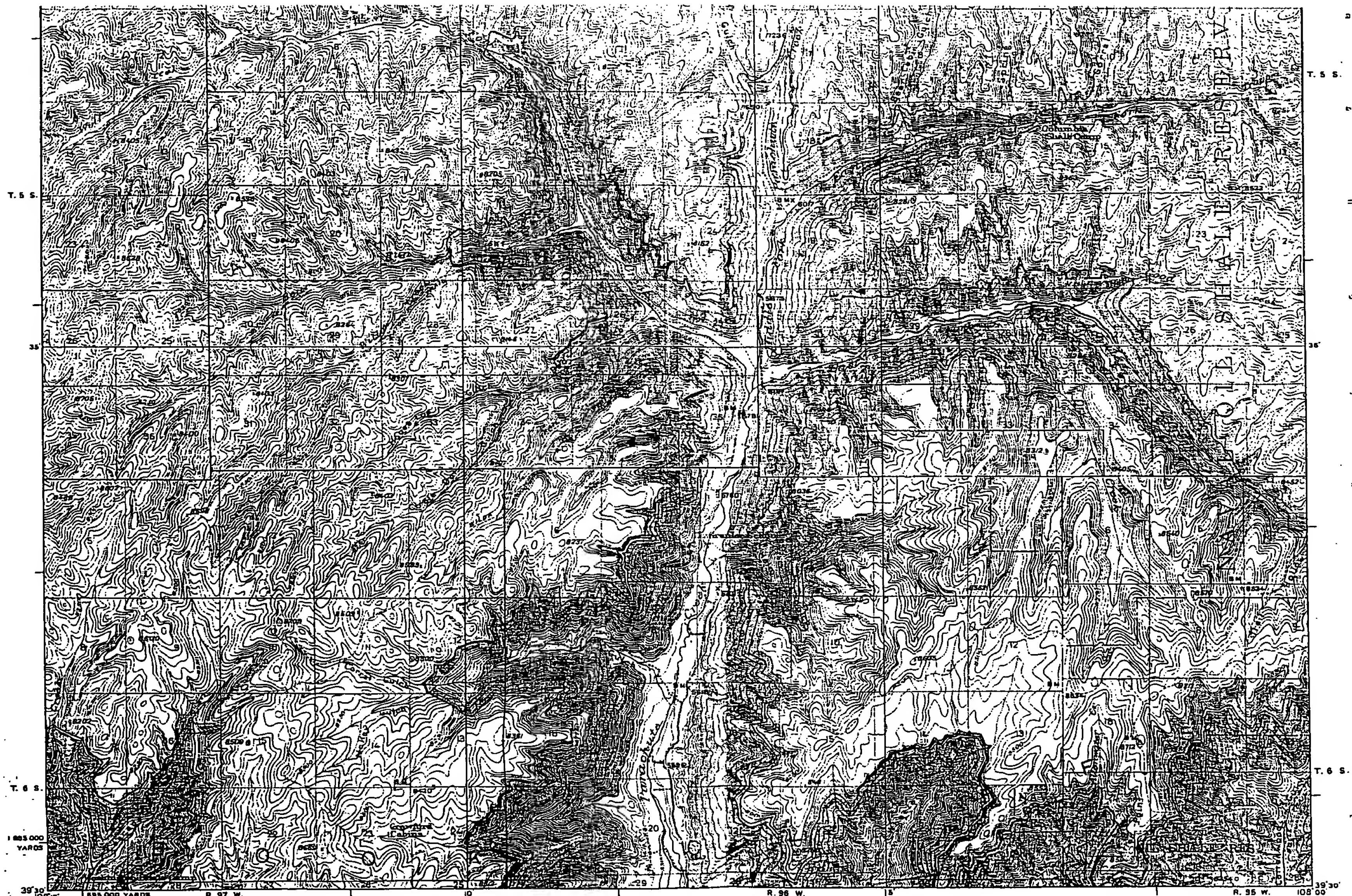
Contour interval 50 feet
Datum is mean sea level

Polyconic projection. North American datum
5000 yard grid based upon U.S. zone system, C

HIGHMORE, COLO.
Edition of 1929.



T. 5 S.
T. 4 S.
T. 3 S.
NAVAL
RES
Gulch
A L E   R E S E R V E



Topography by H.H.Hodgeson, J.B.Leavitt, and G.S.Druhot
Control by U.S.Geological Survey
Surveyed in 1925

Scale 1/62500

Contour interval 50 feet
Datum is mean sea level

Polyconic projection. North American datum
5000 yard grid based upon U.S. zone system, E

PARACHUTE CREEK, COLO.
Edition of 1927

Beträffande report on the testing of Colorado Oil Shale in the HG-retort av Kvarntorp, Sweden, daterad den 17/5 1952.

Delgives: Direktör Wiborgh
Professor Schjånberg
Eventuellt Svenska Maskinverken

Huvudprincipen vid samtliga pyrolysprocesser i Kvarntorp är, att värmen tillföres skiffern indirekt via en retortvägg och icke så,som i de flesta andra fall tillämpas, genom en direkt beröring mellan skiffern och ett värmeavgivande medium, exempelvis förbränningsgaser. Den pyrolysprocess, som utarbetats här, den s.k. Kvarntorpsmetod n, grundar sig på att kolet i den efter pyrolysen kvarstående skifferkoksen förbrännes. Den värme, som härvid uppstår, tillvaratages dels i form av ånga, som genereras i ett vattengenomdrivet tubsystem "La Mont", inbyggt direkt i härden, och d ls i form av heta förbränningsgaser, som på sin väg till skorstenen får omspola retortrar, fyllda med skiffer, som på så sätt upphettas till pyrolystemperatur. Den svenska skiffern ger efter pyrolys en koks med ett bundet värmeinnehåll av ca 1000 kcal pr kg.

Då Colorado-skiffer, avsedd för prov i Kvarntorp, anlände hit, utfördes först en noggrann laboratorieundersökning av skiffern. Man kunde därvid konstatera, vilket också framgår av den rapport, som nu ligger färdig, att den koks, som återstår efter pyrolys av Colorado-skiffer, har ett värmevärde på endast ca 100 kcal pr kg, och det stod från början klart, att Kvarntorpsprocessen i oförändrat skick icke kunde komma till användning för denna typ av råmaterial.

För att emellertid kunna fastställa, hur denna skiffer förhåller sig vid indirekt upphettning, beslöts, att skiffern skulle underkastas prov i en annan typ av retortrar, den s.k. Rockesholmsretortern, som även kommit till tillämpning i full industriell skala i Kvarntorp. Skiffern tillföres även här en retort, som upphettas utifrån på så sätt, att icke kondenserbara pyrolysgaser eller vanlig generatorgas få förbrännas i nederändan av retortern och förbränningsgaserna sedan cirkulera runt retortern,

den / 19

Från VD

innan de föras till skorstenen. Den bifogade rapporten behandlar noggrannt resultaten av de prov, som så utfördes.

Den väsentliga slutsats, som man kan draga av de så erhållna försöksresultaten, är att man får en helt annan och gynnsammare oljekvalitet än vad som är möjligt att erhålla vid den förut omnämnda direkta upphettningen enligt exempelvis Union Oil Company's pyrolysmetod. Vid våra försök erhöllo vi i vissa fall ända till 24 volymprocent bensin. Då uppgifter, hämtade från försök vid direkt upphettning, visa en bensinhalt av 1 - 2 volymprocent, skulle man vara benägen att tro, att vid sistnämnda förfarande bensinen förstöres vid processen och att det följaktligen borde vara möjligt att totalt erhålla ett betydligt bättre utbyte av råolja vid av oss tillämpade förfaranden än t.ex. vid Union Oil Co:s metod. Givetvis kan polymerisation inträda, vilket skulle betyda, att lätta kolväten, som vid vår process ger bensin, vid direkt upphettning uppträder i form av tyngre kolväten, som icke längre tillhöra bensinfraktionen.

Utbytet av olja vid de här genomförda försöken har varit 53 - 88 %. Då det icke är möjligt att under en försöksperiod på några dagar få samtliga på driften inverkande förhållanden så inreglerade, att bästa möjliga resultat erhålles, förvånar detta varierande resultat icke. Ingen anledning finnes emellertid att antaga, att man vid praktisk långtidsdrift skulle erhålla sämre resultat i fråga om utbytet än vad vi genomsnittligt ha nått fram till här i Kvarntorp för vår svenska skiffer, d.v.s. en utbytessiffra på genomsnittligt ca 90 %.

Det är mycket viktigt, att vi nu genom försöken ha fastställt, att den indirekta upphettningen ger kvalitativa fördelar av mycket stor räckvidd. Om man alltså kan bibehålla den indirekta upphettningen men ändå nå fram till den process, som ur värmebalanssynpunkt och i övrigt i ekonomiskt avseende ger minst samma resultat, som erhålles vid den direkta upphettningsmetoden, har man kommit fram till ett förfarande, som bör vara att föredraga framför andra metoder. De årslånga resultat, som nu föreligga beträffande Kvarntorpsmetoden, visa bestämt, att detta förfarande torde vara det ur ekonomisk synpunkt bästa pyrolysförfarande enligt den indirekta principen, som för närvarande föreligger. Om man alltså kan bibehålla huvudprincipen vid Kvarntorpsmetoden även för Colorado-skiffern, trots detta råmaterials låga värmevärde på koksen, kunde man ha nått fram till något, som väl skulle kunna hävda sig. Vid Kvarntorpsprocessen med vår svenska skiffer som råmaterial ha vi för närvarande ett utbyte av nyttiga kalorier, användbara helt utanför ugnen själv, i förhållande till med skiffern totalt tillförda kalorier av ända till 69 %. Om Colorado-skiffern håller

1305 kcal pr kg och oljeutbytet enligt Fisher-provet är 9,7 %, så erhålles ett oljeutbyte av 85 % av Fisher-provets värde. Den kalorimängd, som erhålles i form av olja är 820 cal pr kg skiffer, vilket utgör 63 % av totalt med skiffern tillförd värme. Detta betyder, att om den icke kondenserbara gasen och koksen utnyttjas för att ge den i härden och utanför härden i Kvarntorps-ugnen erforderliga värmen, så skulle processen bli självbärande. Det är svårt att förstå, att man med något annat förfarande, med direkt eller indirekt upphettning, skulle erhålla en bättre verkningsgrad. Samtidigt skulle man ernå de kvalitativa fördelar, som den indirekta upphettningen ger.

Örebro den 4 juli 1952.

Olof Gjört

Branch

3 479 8 LUDVIG LARSSON ÖREBRO

INTERNT TILLÄGG TILL PM BETRÄFFANDE COLORADO-RAPPORTEN.

De synpunkter, jag framfört i bifogade PM, basera sig på de erfarenheter, som gjorts med skiffern från Belgiska Kongo. Värmevärdet i koksen från denna skiffer är till storleksordningen ungefär detsamma som i Colorado-skiffern, och det visade sig då, att vid så liten tillblandning som 12½ % av Kvarntorpsskiffer till Kongoskiffer, erhöll man sådana fyrar i härden i Kvarntorpsugnen, så att pyrolysen i huvudsak kunde fullföjas. Detta leder till den tankegång, som för övrigt professor Mertens och ingenjör Passbau förfäktade, och som vi också accepterade vid diskussionen med dem här i sammanhang med försöken med Kongo-skiffern, att vårt provblock borde ombyggas så att den icke kondenserbara gasen kunde förbrännas i härden vid ugnen. En ytterligare förbättring skulle kunna ernås, om retortrarna förlängdes. Detta är nu möjligt att åstadkomma, då vi ha plåtretortrar. Vi lovade att försöka genomföra detta till slutet av oktober och då fortsätta med proven på Kongo-skiffern. Lyckas detta prov, är ju det hela upplagt för ytterligare försök på samma linjer med Colorado-skiffern. Råmaterial finnes här i tillräcklig mängd. Det primära är nu att konstruera fram en lämplig brännare för pyrolysgasen, och förbränningen bör ske så att förbränningsgaserna direkt hjälpa till att upphetta koksen-askan i härden, så att man får ungefär motsvarande förhållanden som nu råda i Kvarntorpsugnarna med vår skiffer. Jag gör samtidigt uppmärksam på den adress, som lämnats på "The 49th Semi-Annual Meeting of the National Petroleum Association, Cleveland, Ohio, April 17, 1952", vilken separat bifogas. Granskar man de kostnadssammanställningar, som gjorts för anläggning och drift med Union Oil CO:s metod, förefaller det åtminstone vid en ytlig bedömning, som om vi skulle kunna ernå minst lika gynnsamma resultat med Kvarntorpsförfarandet.

Örebro den 4 juli 1952.

Claes Gejrot

Ing. John Pettersson, Ing. Eric
Pettersson, Ing. Astgren

UNITED STATES

DEPARTMENT OF THE INTERIOR

Rifle April 4, 1952

Air Mail

Mr. Hans Wiborgh
Svenska Skifferolje Aktiebolaget
Kvarntorp
Drottninggatan 3
Örebro, Sweden

Dear Hans:

Today, I received your post card from New York City and was very interested to know that you were in this country. I was disappointed that you were unable to pay us a visit in Rifle, but I will be looking forward to your early return to the States.

Mr. Beverly has told me the interesting details of the tests conducted at Kvarntorp on the Colorado oil shale. He has also told me of the wonderful hospitality shown him while in Sweden. I want to thank you and Dr. Gejrot in particular for your many courtesies and the gratifying cooperation given Mr. Beverly during his visit. As only those of us know, who have had the privilege to visit Sweden, your hospitality is always one of the highlights of such a visit.

Please extend our thanks to Arvid Johansson, Dr. Salomonsson, and Åke Brandberg for their personal assistance with the preparations and the conducting of the tests. I was sorry to hear that Professor Schjanberg was not feeling well at the time. Please extend to him my best regards and I hope he is now in good health.

Also, please thank Dr. Hammar, Mr. Hedbäck, John Pettersson, Eric Pettersson and Åke Astgren for their time and assistance in showing Mr. Beverly your many operations at Kvarntorp. It has been interesting to learn of your improvements and expansions which have taken place since my visit.

It is my hope that in the not-too-distant future I may have the opportunity to return to Europe and spend a time in Sweden.

When you or any other employees at Kvarntorp have an occasion to be in the United States, please accept our standing invitation to come to Rifle and give us an opportunity to repay a small part of your hospitality. We enjoyed Arvid Johansson's visit and hope he had a pleasant journey home.

Yours very truly,

Boyd Guthrie
BOYD GUTHRIE, Chief
Oil-Shale Demonstration Branch

Övering. Johansson,
Ing. Salomonsson.

SAVAGE OIL SHALE DEVELOPMENT COMPANY

P.O. Box 112

De Beque, Colorado

John W. Savage

April 9, 1952

Mr. Hans Wiborgh
Svenska Skifferolje Aktiebolaget
Drottninggatan 3, Orebro
Sweden

Dear Hans:

I want to thank you very much for the fine time you showed me in Sweden. Your many thoughtful courtesies and your constant attention not only added to the value of the visit, but also made it an extremely pleasant time.

The first report is finished and distributed. I presume that the "group" will send you a copy. It does not, however, contain anything that you do not know. In comparing distillation curves of shale oils produced by various retorts the HG is far ahead of others. It must be remembered, however, that we must compete with petroleum as well as rival oil shale processes. Also we must compete in dollars and not solely in "quality of oil". Carl Horgren and John Vivian are highly enthusiastic and I have to caution them that much needs to be done before the capital can be acquired for a plant.

Thank you again for the wonderful hospitality in Orebro and please give my warmest regards to your wife and family.

Sincerely yours,

John

John W. Savage

Övering. Johansson,
Ing. Salomonsson.

UNITED STATES

DEPARTMENT OF THE INTERIOR

Bureau of Mines

Box 792

Rifle, Colorado

January 23, 1952

Air Mail

Mr. Hans Wiborgh
Svenska Skifferolje Aktiebolaget
Kvarntorp
Drottninggatan 3
Orebro, Sweden

Dear Hans:

This will acknowledge receipt of your cable of January 19 advising that the starting of the final run has been postponed and that our engineer should arrive February 18. I have been awaiting receipt of the letter mentioned in your cable but since it has not arrived, I thought I had better advise you immediately that Mr. Beverly's arrival time at Orebro has been postponed two weeks. He will now arrive in Hallsberg on the afternoon of February 15 rather than February 1.

We had been advised by Mr. Norgren that your research test runs were scheduled to start January 21 and that any time after February 1 you would be in a position to conduct the test for our observer to witness. Thus, because of this advice we arranged the original schedule for Mr. Beverly. I sincerely hope that the test can now be started February 18 as Mr. Beverly has several other commitments in Europe and it is very difficult to make any additional rearrangements of his schedule. When you receive my letter of January 17, be advised that Mr. Beverly will arrive in Hallsberg via Oslo rather than Stockholm. He is scheduled to arrive in Oslo February 14 and spend that night at the Grand Hotel.

Upon receipt of your cable postponing the tests, I contacted Mr. John Savage and he advised me that he would change his reservations so that he would arrive in Hallsberg on February 15. I beli ve it is his intention to come to Hallsberg from Copenhagen. No doubt he will keep you informed as to his plans.

With kindest personal regards,

Yours truly,

Boyd Guthrie
BOYD GUTHRIE, Chief
Oil-Shale Demonstration Branch

, Sweden,
January 29, 1952.

Mr. Carl A. Norgren,
3400 South Elati St.,
E n g l e w o o d, Colorado.
U.S.A.

Dear Carl:

Today I received a letter from Boyd Guthrie dated January 23. Since I do not know whether you have received a copy one is enclosed for your knowledge.

/.

Everything is now arranged for the test runs to start February 18. Mr. John Savage will also witness the test runs as mentioned by Boyd Guthrie in his letter and also in an earlier letter dir ct from him.

Just for the case of formality we should like to have your verification that Mr. Savage acts as your observer and that he is your trustee and will not misuse his mission as your man. In fact, we have earlier talked about Mr. Savage but no formal authorization has been extended by you or your group. He is naturally very welcome but we like to have all things straight when starting the tests.

With kindest personal regards,

Sincerely yours,

H.C. Wiborgh
Vice President in Charge
of Sales

Kopia till Dir. Gejrot,
Prof. Schjånb rg,
Övering. Johansson,
Ing. Salomonsson.

, Sweden,
January 29, 1952.

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
United States Department of the Interior
Bureau of Mines,
Box 792,
R i f l e, Colorado.
U.S.A.

Dear Boyd:

Today I received with thanks your letter of January 23 and have already filed your earlier letter dated January 17 regarding Mr. Beverly's Swedish itinerary. Following is noted.

1) Mr. Beverly will arrive in Hallsberg on the afternoon Friday February 15. Since there are several train connections between Oslo and Hallsberg kindly ask Mr. Beverly to send us a cable from Oslo stating which train he arrives on.

2) Mr. John Savage will also arrive in Hallsberg on the same date as Mr. Beverly, probably from Copenhagen. Kindly also advise Mr. Savage that we would appreciate to obtain a cable from him regarding his train schedule.

3) We will meet the two gentlemen in Hallsberg and have booked two single rooms at "Stora Hotellet" in Örebro. Of course, we will also see to it that they will have a nice visit in Sweden.

To-morrow January 30 we will start charging the HG-retort prepared for the test runs with Swedish shale following up this operation in next week by charging Green River shale as formerly advised. Everything will be ready for the test runs to be witnessed when your observers arrive. Since February 16 is a Saturday this day may be spent for a general inspection of our activities. In consequence we rest assured that Mr. Beverly without any difficulties can attend his other commitments in Europe.

All here are naturally sorry that you could not arrange to come over yourself. However, as it is intended these pending test runs will probably be followed by several discussions and negotiations and then I hope we meet in person again.

With kindest personal regards,

Sincerely yours,

H.C. Wiborgh
Vice President in Charge of Sales

Copia till Dir. Gejrot,
Prof. Schjånberg,
Övering. Johansson
Ing. Salomonsson.

Copy to: Mr. Carl A. Norgren.

UNITED STATES
DEPARTMENT OF THE INTERIOR

Bureau of Mines
Box 792
Rifle, Colorado

July 24, 1951

Air Mail

Mr. H.C. Wiborgh
Svenska Skifferolje Aktiebolaget
Kvarntorp
Drottninggatan 3
Orebro, Sweden

Dear Hans:

I was very pleased to note by your letter of July 18 that you received the copy of Si Klosky and my report on Oil Shale Industries of Europe. It was a rather difficult report to prepare as we did not stay long enough in any one place to get sufficiently acquainted with the details of operations as to do justice to the industry, but I am glad that you appreciated our remarks regarding Swedish operations.

Mr. Carl Norgren has communicated with me several times since his return from Europe but unfortunately I have not yet had an opportunity to visit with him. He did advise that Johannsen was devising a very comprehensive program for the testing of the oil shale which we shipped.

Mr. Norgren has advised that you will probably conduct the tests near October 1. Running the tests any time this Fall will be quite satisfactory as far as we are concerned in having an observer witness the runs. I had hoped that I personally could come to Sweden but it looks as though it will be impossible as at the present time we are designing a large-scale Gas-Combustion retort with a bed area of 60 square feet and anticipated capacity of 300 tons per day. We hope to have the retort under construction during the Fall months and this, plus other commitments, will preclude my making any trip to Sweden.

We are arranging, however, for Robert Beverly, a chemical engineer, who has been working on our project for three years, to witness the tests. He has been working on our pilot plant and large-scale retorts and is well informed in oil shale technology as far as we have developed it on our project. It is our plan to have him go to Sweden by air and since reservations are at times difficult to obtain, I would appreciate it very much if you could give me as much advance information as possible as to the time you anticipate making the tests so that necessary arrangements can be made to expedite Beverly's trip.

He is an exceptionally fine young chap and I know you will like him very well. If there is any information he can give you regarding our operations please feel free to discuss matters with him.

I am attaching herewith a report on the mining, crushing, and sampling of the shale which was shipped to you. This report is for your general information and any further details that you feel you would find of assistance, in planning your operations, let us know and they will be forwarded to you. We made every endeavor to ship a representative sample of Mahogany ledge material as it occurs at our place of mining. The average oil content of this shale is 26.7 gallons per ton. As you know, our deposit is quite stratified and we took every precaution we could to thoroughly blend the shale at 26.7 so no difficulty would be experienced in its retorting due to variation of the different beds which compose the 70' strata.

Yours very truly,

Boyd Guthrie
BOYD GUTHRIE
Chief
Oil-Shale Demonstration Branch

Copy to: C.A. Norgren

... ... United States.

U.S.A:s skiffertillgångar.

Främst Green River-formationen från mitten av Eocen-tiden. Ca. 16.500 sq.miles; Colorado, Utah, Wyoming. Den rikaste av hithörande förekomster är Piceance Creek Basin i NV. Colorado, där medelmäktigheten är ~ 500 feet och medelutbytet enl. Fischer är 15 U.S. gallons/ton. Area: 1000 sq.miles.

Den undre delen av förekomsten, den s.k. ~~Mahogy~~-Mahogany Ledge är 70-110 ft tjock och 1000 sq.miles: utsträckning. Medel-Fischer: ~ 30 gals/ton.

Skifferbrytningen: måste göras ekonomisk. Har studerats ingående. Vid en brytning av 150.000 ton/dag kan skiffern brytas och transporteras till en retortanläggning för 58 cents/ton. Ytterligare 2,5 cents behövs för att man skall få 4% på anläggningskostnaderna för gruvan, som uppgå till ~ 34.000 000 $.

Skifferforskning.

Resultat från Laramie och Rifle:

a) Ca. 500.000 BTU behövs för pyrolys av 1 ton genomsnittlig Colorado-skiffer.
b) Oljans olefiner ha raka kedjor
c) Oljan innehåller hög halt heterocykliska ä.
d) Tjärsyrorna innehålla fenol, kresoler, ngt xylenoler o. högre
e) Tjärbaserna — " — subst. pyridiner, och kinoliner.
f) Svavlet föreligger huvudsakligen som subst. tiofener.
g) Goda kristallina och mikrokristallina vaxer kunna fås

[illegible] av 40 ton vardera ha drivits av B.o.M. sedan maj 1947 under olika betingelser. Bästa utbytet 85–90 % av Fischer. Försöken avslutades 1. mars -49. (tillsvidare).

2) Royster-processen: mindre batch unit, ~~s~~ provad ~~sedan~~ jan.–sept. 1948 av B.o.M. Okondenserbar gas upphettas och cirkuleras genom skifferbädden. Avsedd som förförsök till en kontinuerlig retort.

3) Gas-flow-retort: Kontinuerlig retort. B.o.M. Liknar Grand Paroisse. Skiffern (i vertikalt ~~st~~ schakt) förvärmes av rökgaser och pyrolyseras med en horisontell ström av okondenserbara gaser, som värmas genom förbränning av skifferkoksen och cirkuleras.

4) ~~C~~ Union Oil's retort: Samma princip som NTU (inre förbränning) men kontinuerlig. Skiffern inmatas av en hydraulisk piston underifrån genom förvärmnings-, pyrolys- och förbränningszonerna och askan avskrapas upptill. Luften och gaserna sugas ned genom skiffern och förvärma densamma, och kondensationen av oljan sker i den kalla skiffern. Drives av Union oil of California i samarbete med B.o.M.

5) Fluidiserings-metoden: Standard Oil Development Co och B.o.M. Försök i Baton Rouge, La.

6) Thermofor-~~st~~-processen: Socony-Vacuum Oil Co. Vertikal kontinuerlig retort i vilken skiffern sjunker genom förv., pyr. [illegible]

...ase alltid av kompromisser mellan olika krav. I västra Colorado är vattentillgången knapp och måste reserveras för "municipal use". Lämpliga är där endast sådana metoder, som ej kräva mycket kyl- o. annat vatten.

Det synes vidare vara nödvändigt, att en komplett anläggning använder olika retorttyper för de olika kornstorlekarna, eftersom varje retorttyp arbetar bara med en viss kornstorlek.

Ekonomi.

B.o.M. uppskattar att olja bör kunna produceras ur skiffer i närheten av Colorado till ett pris av $ 2,40/bbl ur 30 gals/ton – skiffer om man använder NTU-retorter och gör 100.000 bbls/day. Inkluderar 6 2/3 % avskrivning per år, men icke ränta på investeringen.

Socony-Vacuum Oil Co, anger för Thermofor-processen under likn. förhållanden $1.10/barrel (excl. byggning), $1,25 /barrel (inkl. byggning).

1.-X-51. Försöksanläggningen i Rifle, Colo.

I en experimentgruva studeras brytningen av skiffern. Berget är relativt fast och tillåter uppslagande av stora rum. Brytning och lastning kan därför ske maskinellt, vilket ger hög avverkning: 100-120 ton/arbetare o. skift.

Dessutom en mindre, s.k. selektiv gruva, varifrån alla slags skiffrar för försöksdrift kan brytas (från 1 till 80 gals/ton.)

Genomsnittlig oljehalt enl. Fischer är ~30 gals/ton och gasutbyte = ~2,5%.

Pyrolys i 2 diskontinuerliga NTU-retorter om vardera en kapacitet av 40 ton. Endast provisoriska (för tillv. av material för oljeundersökning.)

Dessutom ett spec. "pilot-plant"-retort-lab. Två retorttyper äro spec. intressanta: den diskontinuerliga Royster-retorten (även kallad Jo davis-r.) samt den kontinuerliga "gas-flow"-retorten. I båda fallen sker pyrolysen genom att en inert, i en yttre heater upphettad gas ledes genom skiffermassan. God värmeöverföring, mindre risk för överhettning. Oljeutbyten: ~110% av Fischer.

Även försök i Union Oils retort i Wilmington Cal, i Standard Oils "fluid solid"-retort i Baton Rouge, La, och i B.o.M:s försöksstation i Golden, Col. i Parry-retorten.

Forskningslaboratoriet i Laramie.

Skifferoljesektionen är delad på följ. underavdeln.:

a) Skifferundersökn. och [illegible]

c) Skifferolyeanalys.
d) Biprodukter.

A) Skifferpyrolys och raffinering.

Pyrolysen studerades i en adiabatisk apparat för best. av värmebehov.

En ny pyrolysmetod studerades (Thermal Solution Method) där skiffern före pyrolysen blandades med gasolja. Totala oljeutbytet förbättrades, men krackningen av gasolja var så intensiv, att sådan måste tillföras från annat håll, varför processen ansågs mindre lämplig för större drift.

B. Skifferanalys.

Ca 2% bitumen, lösligt i bensol, finns i skiffern, men återstoden, kerogenet, är icke lösligt i några kända lösningsmedel. Om dess natur vet man föga, och de formler man angivit, anses man endast vara arbetshypoteser. Man tänker sig kerogenet bestå av annellerade bensolkärnor, liknande chrysen, pyren etc. med relativt långa sidokedjor. (Det bör observeras, att den amerik. skifferoljan håller fasta paraffiner, vilka helt saknas i den sv. skifferoljan.) För renframställning av kerogenet extraherades karbonater med HOAc, varefter återstoden anrikades enl. sink-float-metoden med bensol-CCl_4-blandningar, varvid slutligen ett koncentrat med blott 9,2% aska erhölls. På detta kon- bestämd- ...

följa rätt väl en 1:sta ordningens reaktion. Försöksdata ha samlats i kurvor som ge möjlighet att beräkna sönderdelningen vid olika temperatur och pyrolystid.

Studier av oljeskiffrar i Rifle, Colorado.

Inledning:

Vid avresan från Los Angeles österut överenskoms med direktör Limden om ett besök vid Bureau of Mines' experimentanläggning i Rifle, Colorado. Från början avsåg direktör Linden att följa med dit, men han fick förhinder och skrev istället ett introduktionsbrev åt mig till chefen för anläggningen, Mr. Boyd Guthrie. Tyvärr föll det sig så att denne var bortrest vid tiden för mitt besök, men hans assistenter togo väl emot mig och gav mig tillfälle att se allt jag önskade och gav mig många värdefulla upplysningar.

I: Diskussioner och studier vid besöket.

Besöket ägde rum torsdagen och fredagen den 15 - 16 april, 1948. Anläggningen ligger på en bergssluttning cirka en svensk mil väster om den lilla staden Rifle.

Jag togs emot av Mr. Mull, som är Mr. Guthries assistent och tillika chef för laboratoriet. Han introducerade mig för Mr. Siprelle, tydligen metodikingeniör för gruvdriften, och även för Mr. Carl Belser, gruvingeniör.

Mr. Mull visade mig omkring på anläggningen, som verkade mycket välskött. Jag fick obehindrat fotografera vad jag ville och har tagit en hel mängd fotos i färg, som i någon mån ger en föreställning om anläggningens detaljer, men framförallt ger en bild av skifferlagrens läge och mäktighet.

Det nya raffinaderiet är man i full gång med att montera, men det torde ännu dröja några månader innan det kan sättas i drift.

Efter en slingrande bilfärd uppför bergssluttningen från retortanläggningen på 1750 m. höjd över havet till gruvan, som ligger på 2500 m. höjd, 7 miles väg från anläggningen, sammanträffade jag med Mr. Belser, som visade mig gruvanläggningen i detalj och gav mig diverse uppgifter om skifferns lagring och egenskaper. Han hjälpte mig även välvilligt med de provstycken av skiffern, som jag sände hem till Sverige.

Efter den andra dagens besök fick jag tillfälle att flyga över området med ett sportplan av typ Cessna, som en farmare i Rifle var vänlig nog att taga mig upp i på en 45 minuters flygning för enbart bensinpriset. Jag tog därvid åtskilliga färgbilder och även en 8 mm smalfilm, i färg, som kommer att överlämnas till Skifferolje A.B.

II: Synpunkter på skifferlagrens läge och omfattning.

Beträffande diverse data för såväl anläggningen som skiffern, hänvisas till tre tidigare översända artiklar, enligt följande:

1) "Oil Shale Resources of Colorado, Utah and Wyoming", by Carl Belser.

2) "Oil Shale Processing ....."

3) "Oil Shale Mining by Tell Ertl.

Dessa benämnas nedan ref. (1) , etc. eller bilaga 1 etc.

Det relativt lilla område, där Colorado, Utah och Wyoming gränsa till varandra och där oljeskiffrarna ligga relativt koncentrerade, omfattar så mycket som ungefär 80 % av all oljeskiffer i USA. Skiffrarna äro rika jämfört med den svenska skiffern och beräknas innehålla cirka 300 miljarder barrels olja (ung. 50 x 10^9 m^3), varav 90 % finnes enbart i Coloradoskiffern. (Enligt ref. 1). Dessa siffror äro emellertid osäkra.

De bergmassiv som Green Rivers formationen omfattar utgöra en imponerande anblick och äro onekligen svårtillgängliga i all sin vildhet och brant-het. Skifferlagren skjuta så gott som överallt ut i dagen i de övre delarna av de branta och mångfaldigt förgrenade bergskammarna och det rikaste cirka 150 meter djupa skifferlagret, som är plant skiktat inom stora områden, lutar något mer än 1° nedåt i riktning mot nord-nordöst.

Inom stora områden vid sidan om Parachute Creek (invid vilken försöksanläggningen ligger), finnas skifferlager med en mäktighet om upp till 400 m., dock skiktade i fleraalager med mellanliggande lager av andra bergarter.

Vertikalsektioner i ref.(1) ge en god bild av skifferns skiktning och visar även det oregelbundna täcke av fin grå och brun sandsten, den s.k. "Evacuation Creek", som varierar ganska kraftigt i tjocklek från c:a 200 meter till 0 m. vid området närmast försöksanläggningen. Man ser att det finnes vissa partier, där detta täcke är genombrutet eller ganska tunt, men större delen av arealen är täckt av ett ganska tjockt sandstenstäcke.

Emellertid finnas i de ganska vitt förgrenade floddalgångarna, t. ex. i "East Middle Fork, Parachute Creek", ganska stora areor, där skifferns övre skikt ligga helt i dagen och där de rikaste lagren ligga på måttligt djup. Se bifogade tre kartor över områden väster om Rifle, bilagorna 4 - 6. (Dessa ha endast bilagts ex. 1-3 av rapporten). Gruvan ligger alldeles under krönet av de vertikalt stupande skifferlager, som komma ut i dagen och är tämligen svårtillgänglig. Man har byggt en väg, som i skarpvinkliga zick-zack-linjer leder upp till gruvan och är 7 miles lång. Det är mycket besvärligt att ta sig upp på de ovanför gruvan belägna bergformationerna.

En fältdrift däruppe enligt Ljungströmsmetoden skulle innebära ganska stora svårigheter.

III: Skifferlagrens oljehalt.

Denna anges i USA i gallons per ton, d.v.s. i enheter om 3,785 liter per 2000 pounds. Vid medelvärdet å specifika vikten γ = 2,40 (som gäller vid 15 gal/ton), motsvarar värdet i gal/ton exakt oljehalten i volymsprocent.

Enligt ref. (1) (bilaga 1), har man i närheten av gruvan

c:a 90 m. tjocka lager med över 15 volyms-% olja och

c:a 20 m. tjocka lager med över 30 volyms-% olja.

Medelvärdet av två provhål ger 110 m. tjockt lager med i medeltal 18,7 volyms-% olja, varav de rikaste lagren med i medeltal 30 volyms-% olja

äro 25 m. tjocka (invid den s.k. "Mahogany marker"). Dessa äro som ovan nämnts belägna ganska nära markytan i vissa dalgångar. Lokalt i tunna lager kan oljehalten uppnå det fantastiska värdet 60 volyms-% (över 80 gal/ton vid spec. vikten 1,6)

IV: Skifferns egenskaper, fysikaliska data, m.m.

Egenskaperna hos den ur Coloradoskiffern med hittills använda metoder utvunna oljan behandlas icke här. De kunna studeras i bilaga 8 - 9, som erhållits från Mr. Mull, eller i Bureau of Mines' Bulletin 415: "Studies of Certain Properties of Oil Shale and Shale Oil" av Boyd Guthrie. (Bil. 8-9 har endast bifogats ex. 1 av denna rapport.)

Själva skiffern studerade jag ganska ingående i och utanför gruvan och tog en mängd färgfotos av den.

Färgen är ganska likartad Kvarntorpskifferns, men varierar ganska kraftigt och är som regel ljusare, speciellt där den är i dagen.

Man fick ett bestämt intryck av att denna Coloradoskiffer är fastare, tätare och mindre sprickigt skiktad än Kvarntorpsskiffern. Sålunda föreföllo de flesta losssprängda stycken, som jag såg, att vara mera spaltade vinkelrätt mot skiktriktningen än parallellt med denna. Det var faktiskt svårt att välja ut det provstycke, som jag skickat hem och som har sina största dimensioner i skiktningens plan.

Tätheten visar sig även däri, att man har mycket litet grundvatten i Gruvan.

Några inneslutningar liknande orstenen i Kvarntorp tyckas inte finnas. Brytningen synes dock gå relativt lätt och man räknar med att kunna få ned brytningskostnaden till 50 cents per ton vid stordrift.

Fysikaliska data: (och kemiska)

Följande data för skiffern erhöllos vid besöket:

Skifferns sammansättning enligt Fischeranalys: (vid oljehalt 25-30 gal/ton)

Olja:	26,7 gal/ton,	10,4 vikts-%
Vatten:	3,3 "	1,4
Resterande skiffer		85,7
Gas + förluster		2,5
	Summa	100,o

Kemisk sammansättning av rå skiffer (oljehalt enligt ovan)

Ämne nr.	Formel	Procenttal
1	SiO_2	26.4
2	Fe_2O_3	2,6
3	Al_2O_3	6,6
4	CaO	17,1
5	MgO	5,4
6	SO_3	0,6
7	Na_2O	2,7
8	K_2O	1,o
9	CO_2	20,0
10	N_2	0,54
11	P_2O_5	0,35
12	V_2O_5	0,oo3
	Summa	83,293
	Organisk substans + vatten	16,707
	Summa	100,o

Nr. 1-6 ha bestämts ur aska,
nr 7-12 ur rå skiffer.

Oljehalt i gal/ton:	0	10	15	20	30	40	60	80
Specifik vikt γ =	2,76	2,53	2,42	2,32	2,16	2,03	1,81	1,6

Skifferns specifika värme vid 77°F.

Oljehalt i gal/ton:	1	10	20	30	40	50	60
Spec. värme s kcal/kg °C:	0,21	0,22	0,23	0,24	0,25	0,26	0,27

Generellt gäller formeln:

$$s = 0,172 + (0,067 + 0,00162 \times G) \times T \times 10^{-3} \quad kcal/kg\ ^{\circ}C,$$

där G = oljehalt i gallons/ton
T = temp. i °F absolut

Vid 30 gal/ton är γ = 2,16 och s = 0,24 kcal/kg °C. Detta motsvarar
S = 2160x0,24 = 520 kcal/m^3 °C., d.v.s. något lägre än värdet
575 kcal/m^3 °C som gäller för Kvarntorpsskiffern.

Skifferns värmeledningsförmåga: Inga data tillgängliga.

Data för de hemsända skifferproverna:

Två prover av medelrik och mycket rik skiffer ha av undertecknad sänts från Rifle till Svenska Skifferolje A.B., emballerade i en trälåda.

Det större skifferstycket väger 35 kg och är taget i medelrika lager straxt över mahogany marker och Mr. Carl Belser uppskattar att det håller cirka 25 - 30 gallons olja per ton.

Det mindre stycket väger 5,5 kg och är taget i det rikaste lagret cirka 14 fot under mahogany marker och uppskattas hålla cirka 65 - 70 gallons olja per ton.

V: Tillgångar till elenergi.

Enligt uppgift från Mr. Mull finnas följande kraftstationer inom rimligt avstånd från Rifle:

1)	Hoover Dam, med nuvarande kraftbelopp	1.435.000 hkr
	" slutligt framtida kraftbelopp	1.835.000 hkr
2)	Green Mountain, vid Blue River, just utbyggd	30,000 hkr
3)	Estes (?) P. (klar 1949)	63.000 hkr
4)	Mary's Lake "	11.300 hkr
5)	Glenwood Canyon (Shoshone)	15.000 hkr

I Coloradofloden nära Rifle finnas enligt Mr. Mull endast ett par ställen med fördämningar med cirka 2 meters höjdskillnad, där man skulle kunna anlägga mindre kraftstationer. Direktör Linden är emellertid av den åsikten att det finnes stora outnyttjade vattenkrafttillgångar i omgivningarna.

Staten kan leverera kraft till ett pris av c:a 0,25 cent/kWh, men som regel vill man ej åtaga sig distributionen, utan säljer kraften till privata bolag, som tar hand om distributionen och därvid begära c:a 0,8 cent/kWh.

Vid Bureau of Mines' försöksanläggning har man för närvarande installerat tre små transformatorer om vardera 500 kW effekt, d.v.s. man har tillgång till endast 1500 kW, som nästan helt utnyttjas för den normala driften.

Det är sålunda tydligt, att för försök i samma storleksordning som Norrtorp I måste en ny kraftledning anläggas. Möjligen kan ett försök i samma storleksklass som det första försöket vid Östersäter genomföras med den nuvarande krafttillgången.

VI: Synpunkter på möjligheter till Ljungströmsmetodens tillämpning i Rifle.

Nedan studeras två alternativ, nämligen a) drift i ett ung. 100 m. djupt lager med medelutvinningen 15 gal/ton, och b) drift i ett 20 m. tjockt lager med ung. 30 gal/ton utvinning. (enligt Fischeranalys)

a) Skiffer med 15 gal/ton oljehalt (enligt Fischeranalys)

Specifika värmet blir, med s = 0,225 kcal/kg °C och γ = 2,42 kg/dm^3:

$$S = 2420 \times 0{,}225 = 550 \text{ kcal/m}^3 \text{ °C}$$

Antag uppvärmning 380°C. Antag vidare att Fischeranalysens oljehalt reduceras till 75% vid pyrolys in situ.

Antages vidare 10 % förluster på grund av värmeavledning, blir den erforderliga elenergien per m^3 skiffer, d.v.s. per 0,75 x 150 liter olja som utvinnes,

$$W = 550 \times 380 \times (1/860) \times 1{,}10 = \underline{270 \text{ kWh/m}^3 \text{ skiffer.}}$$

Således blir energibehovet per liter producerad olja

$$W_1 = 270/0{,}75 \times 150 = \underline{2{,}40 \text{ kWh/liter.}}$$

Vid 0,25 cent/kWh motsvarar detta 2,2 öre per liter.

b) Skiffer med 30 gal/ton oljehalt. (ung. 300 liter per m^3 skiffer enligt Fischer)

Enligt sid. 4 gäller för denna $S = 520$ kcal/m^3 °C.

Med samma procentuella utvinning 75 % av Fischervärdet, men med något större värmeförluster i det nu betydligt tunnare skifferlagret, förslagsvis 15 %, fås $W = 520 \times 380 \times (1/860) \times 1{,}15 = 265$ kWh/m^3 skiffer,

och $W_1 = 265/\ 0{,}75 \times 300 = \underline{1{,}20 \text{ kWh/liter.}}$

d.v.s. energikostnaden blir endast 1,1 öre per liter.

Synpunkter på total produktionskostnad.

Ing. Söderbaum har i en utredning av d. 3/5 1948 beräknat kostnaderna för ett fält i Rifle med 100 m^2 area och 150 m djup, d.v.s. volymen 15.000 m^3 skiffer.

Därvid har en så låg oljeutvinning som 55 % av Fischeranalysens värde 15 gal/ton antagits. Något optimistiskt, men mera sannolikt är att 75 % kan utvinnas som antagits ovan. (ingen orsten i Coloradoskiffern bl an)

Skifferns specifika värme har vidare satts så högt somtill 750 kcal/m^3 °C, vilket enligt ovan är c:a 35 % för högt.

Vidare har borrningskostnaden antagits vara tre gånger så hög som vid Norrtorp och elementkostnaden 50% högre.

Trots detta har ingeniör Söderbaum i sin utredning erhållit resultatet att produktionskostnaderna skulle bli $ 2,35/barrel vid 15 gal/ton oljehalt (liksom i alternativ a) ovan)

Härvid har elenergiåtgången, med avdrag för med skiffergas producerad egen elkraft, beräknats till 1,9 kWh/liter, att jämföras med värdet enligt alt a) ovan, 2,40 kWh/liter utan avdrag för egen elkraft.

Vid alt. a) utan egen elkraft bortfalla tilläggskostnaderna för ångkraftgenereringen och om man räknar med de enligt nämnda alt. antagna något gynnsammare siffrorna för procentuell oljeutvinning och spec. värme, torde oljeproduktionspriset stanna vid c:a $ 2,oo per barrel, ett värde som undertecknad tidigare uppskattat.

Vid drift enligt alternativ b) med tunnare skifferlager med 30 gal/ton oljehalt, torde priset kunna bli avsevärt lägre, men endast en liten del av hela skifferkroppen utnyttjas därvid och alternativet är därför olämpligt, såvida det icke kan tillämpas i kombination med brytning av skiffern, varvid även de annars mycket oekonomiska borrhålsdjupen kan reduceras till ett minimum.

Kombination av brytnings- och Lj-metoden.

Vid den brytning, som nu planeras, har man tänkt sig att spränga ur 75 % av skifferkroppen i relativt grunda horisontella schakt, där man lämnar kvar kvadratiska stödpelare med 50 fots sida.

Man kan eventuellt tänka sig att inne i dessa schakt med sin relativt plana golvyta utföra borrning nedåt av värme- och gashål och driva av de underliggande lagren med Lj-metoden. Härvid får givetvis speciella rörnedsättningsmetoder tillämpas, (brännsvetsning av korta rördelar eller nedsättning av rör som lindats bockade på trummor) men metoden är fullt tänkbar. Den skulle innebära en fördel därigenom att horisontella utgångsplan för borrningen åstadkoms och att borrningen genom tjocka, högt belägna och starkt kuperade sandstenstäcken undveks.

Visserligen finnas horisontella markplan om 10-20 acres här och var över skiffern, men den ovan skisserade kombinationsmetoden skulle kunna ge en hög utnyttjningsgrad för hela skiffervolymen och ej begränsa Lj-metodens tillämpning till enstaka markpartier. Svårigheter med ventilation inne i schakten förutses emellertid.

Förslag till försök i halvstor skala:

Under alla omständigheter torde det vara lättvindigast att göra försök i halvstor skala inne i gruvan. Man har nu brutit ut en stor kammare med höjden 8 m, bredden 15 m och stor längd. Höjden kommer att ökas till 21 m.

I detta gruvschakt bör det kunna gå bra att sätta ned ett mindre antal element och genomföra ett försök i en skala liknande Östersäterförsöket.

Möjligheter finnas givetvis även till försök i floddalgångar, där skiffern går i dagen och de rika lagren ligga relativt grunt, men en ny kraftledning måste då troligen dragas till försöksplatsen och vidare blir avståndet till Bureau of Mines försöksanläggning med sina tekniska resurser en olägenhet.

Diverse data av intresse:

Total råoljeförbrukning inom USA är för närvarande c:a 2.250.000.000 barrels/år = 6×10^6 barrels/dygn = 4000 gånger totalproduktionen i Kvarntorp vid fulldrift.

De 300 miljarder barrels som uppskattas finnas i Colorado, räcka vid denna förbrukning i 130 år.

Om så mycket som 10 % av denna väldiga oljemängd skulle produceras med Lj-metoden, d.v.s. $0,6 \times 10^6 \times 159$ liter/dygn = 4×10^6 liter/tim, åtgår vid alt. a) enl. ovan ,(15 gal/ton oljehalt), den ungefärliga effekten $2,4 \times 4 \times 10^6$ = 10 miljoner kW, d.v.s. i det närmaste 10 kraftstationer av Hoover Dams kapacitet. Som synes är det tämligen omöjligt att en verkligt betydande del av USA:s oljebehov inom överskådlig framtid skulle kunna framställas med Lj-metoden tillämpad på dessa skiffrar, men det är sannolikt att den bättre oljekvalitet, som man kan vänta sig vid denna metod jämfört med retortmetoderna ger den berättigande för vissa speciella behov, då oljeskiffrarna måste tillgripas på allvar och i stor skala i USA.

Det är för övrigt även mycket svårt att tänka sig att man med gruvbrytning och retortbehandling av skiffern skall kunna producera ens en liten bråkdel av USA:s oljebehov. Raffineringssvårigheterna äro därvid för övrigt mycket stora än så länge.

Elenergi framställd med koleldade ångkraftverk kostar c:a 0,7 cent/kWh

Mr. Mull uppger att i Journal of the Institute of Petroleum , okt. el. nov. 1947, finnes en artikel om Fluid Cracking Process Applied to Shale Retorting , som är mycket intressant.

Vid kärnborrning för provtagning i enstaka hål anser man att borrpriset är $ 7,50 per fot, ett mycket högt värde.

Linköping, den 27 juni 1948

Olle Ljungström

Olle Ljungström

Bilagor:

1 - 3: Bureau of Mines' Publikationer enligt lista å sid. 1 (endast ex. 1 av rap).

4 - 6: 3 kartor över Parachute Creek , Highmore och Roan Creek , Colorado (endast bilagda ex. 1-3 av rapporten)

7: Data för Coloradoskiffer } (endast ex. 1 av rap.)

8-9: " " " " -olja. }

10: Färgbilder från Rifle. (- " -)

11: 8 mm färgfilm tagen från luften över Rifle. (- " -)

(Grade 25–30 gallon/ton)

SOURCE: Bureau of Mines, Oil Shale Mine, Anvil Points, Rifle, Colorad .

FISCHER ASSAY:

OIL, GAL./TON	26.7
WATER, GAL/TON	3.3
Oil, PERCENT	10.4
WATER, PERCENT	1.4
SPENT SHALE, PERCENT	85.7
GAS PLUS LOSS, PERCENT	2.5
TOTAL	100.0

COMPOSITION OF RAW SHALE:

Item	Constituent	Percent
1	SiO_2	26.4
2	Fe_2O_3	2.6
3	Al_2O_3	6.6
4	CaO	17.1
5	MgO	5.4
6	SO_3	0.6
7	Na_2O	2.7
8	K_2O	1.0
9	CO_2	20.0
10	N_2	0.54
11	P_2O_5	0.35
12	V_2O_5	0.003
	TOTAL ABOVE	83.293
	ORGANIC PLUS WATER (BY DIFFERENCE)	16.707
	TOTAL	100.0

ITEMS 1 THROUGH 6 DETERMINED ON ASH, CALCULATED TO RAW SHALE, ITEMS 7 THOUGH 12 DETERMINED ON RAW SHALE.

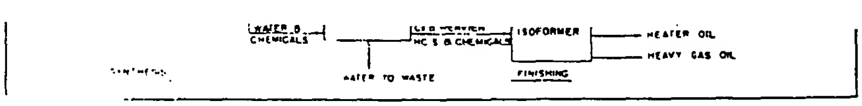


Fig. 2—Synthetic fuels from coal

t least be obtained from known United States shale deposits.[1] The recovery of oil from shale is a commendable conservation measure since oil shales in their natural state are not useful

Lab. Sample No. Representative Tank Sample Date Analyzed

Source of Shale Demonstration Plant Mine Date Sampled 1/28/48

Eduction Method N-T-U Retorts Eduction Date

SUMMARY OF PROPERTIES

Properties of Crude Shale Oil

Sp. Gr. 60/60°F.	.939
A P.I. Gravity	19.2
Sulfur, Percent	.8
Nitrogen, Percent	1.8
Pour Point, °F.	90
Viscosity, S.U. Seconds at 100°	

Distillation Summary

	Percent	Sp. Gr.	°A.P.I.	760mm
Naphtha (Fractions 1-7)	2.9	.839	37.2	-200°C
Light Distillate (Fractions 8-11)	14.8	.876	30.0	-310°C
Heavy Distillate (Fractions 12-15)	40.1	.925	21.5	-430°C
Residuum	39.9	.989	11.6	—
Loss	2.3	—	—	—

ANALYTICAL DATA

Distillation at 760 MM. HG. Pressure

Fraction No.	Cut at °C	Cut at °F	Per-cent	Sum Percent	Gravity Sp. Gr. 60/60°F.	Gravity °A.P.I. 60°F
1	50	122				
2	75	187				
3	100	212				
4	125	257				
5	150	302				
6	175	347	.8	.8)	.839	37.2
7	200	392	2.1	2.9)		

Naphtha Composite (Fractions 1-7)

	Percent
Tar Acids	
Tar Bases	Insufficient
Neutral Oil	Sample
Paraffins and Naphthenes	
Olefins	
Aromatics*	

* Including sulphur and nitrogen compounds

Distillation at MM. HG. Pressure

Fraction No.	Cut at °C	Cut at °F	Per-cent	Sum Percent	Gravity Sp. Gr. 60/60°F	Gravity A.P.I. 60°F	Viscosity K. V. Centi-Stokes	Viscosity S.U.V. Sec.	Anoline Point °C	Cloud Test °F
8	125	257	—	2.9	—	—	—	—	—	—
9	150	302	3.0	5.9	.856	33.8	2.06	32.8	—	—
10	175	347	5.5	11.4	.873	30.6	2.98	36.0	—	—
11	200	392	6.3	17.7	.869	27.7	5.17	42.5	—	—
12	225	437	7.3	25.0	.903	25.2	9.06	55.5	—	—
13	250	482	9.7	34.7	.918	22.6	18.14	89.8	—	—
14	275	527	11.2	45.9	.930	20.6	42.75	197.9	—	—
15	300	572	11.9	57.8	.940	19.0	75.45	348.6	—	—

RESIDUUM

Carbon Residue of Residuum 9.49 Percent; Carbon Residue of Crude 3.9 Percent

Ash on Residuum .07 Percent; Ash on Crude .02 Percent

NOTE: Cuts too dark for aniline point and cloud test.

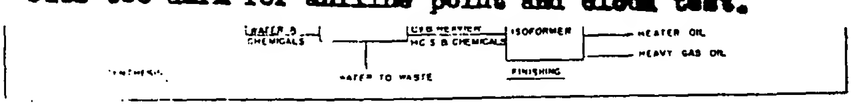


Fig. 2—Synthetic fuels from coal

at least be obtained from known United States shale deposits.[1] The recovery of oil from shale is a commendable conservation measure since oil shales in their natural state are not useful

Analysis No. ...

A.S.T.M. DISTILLATION TEST

DATE 1/28/43 SAMPLE NO. Representative Tank Sample

TIME

SAMPLE SOURCE Crude N-T-U Shale Oil from Tank 515.

SUBMITTED BY Transferred to drums on 1/28, 2/3, and 2/6/43

PER CENT	TEMP. °F	Temp. °F (760mm)		
I.B.P.	310	324	GRAVITY	
2 / 5	422 / 463	438 / 479	A.P.I. 60°F	19.2
10	508	524	Spg. 60/60°F	.939
20	576	594	COLOR	
30	618	636	DOCTOR	
40	640	658	CORROSION	
50	655	673	FLASH C.O.C.	265°F
60	668	688	R.V.P.	
68	680	700	VIS S.U. @ 210 °F	55 Sec.
80			Pour Point, °F	90
90			% Water	0.5
95				
E. P.			REMARKS	
RECOVERY				
RESIDUE				
LOSS				
BAROMETER 624 mm. (Avg)				

ANALYZED BY Wood-Shaw DATE

APPROVED BY A. S. Houghton

NOTE: Incipient cracking at 680°F/624 mm.

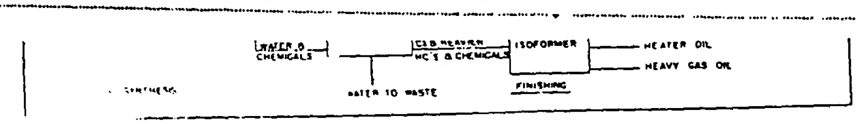


Fig. 2—Synthetic fuels from coal

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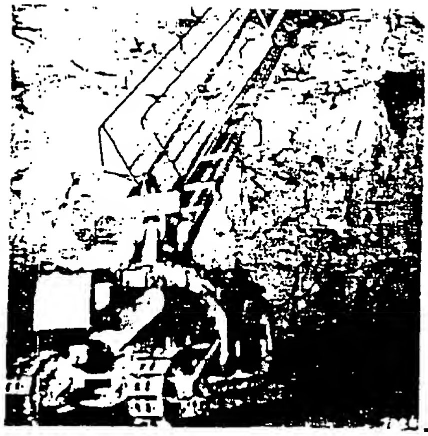

PRODUCTION OF

LIQUID FUELS FROM COAL AND OIL SHALE

by George Roberts, Jr., and Paul R. Schultz

THE three important raw materials that can be used to supplement or replace crude petroleum as sources for liquid fuels are natural gas, oil shale, and coal. Of these, natural gas is the least important because of limited availability. It is finding a profitable and essential market as domestic and industrial fuel, and the reserves in excess of these applications could provide only a few per cent of the demand for liquid fuels. Although of minor importance from the standpoint of potential volume, the development of synthetic liquid fuels from natural gas has led industrial research efforts in the synthesis field since it appeared to be the most economically attractive of all of the synthesis processes.

Production of liquid fuels from coal and shale has been developed on a commercial scale in numerous foreign countries, particularly Germany. However, the processes as developed abroad are financially unattractive in the American economy, and hence are of little interest in the present discussion. The synthesis of liquid fuels from natural gas has not been practiced in foreign countries, but this process is now nearing commercialization in the United States.

In order to evaluate the comparative economics of liquid fuels from coal and oil shale, it was necessary to postulate representative cases, formulate workable plant designs, and estimate investment and operating costs for each case. Three basic cases were selected, one on oil shale, one on bituminous coal, and one on subbituminous coal. Nominal capacity of each plant was fixed at 10,000 bbl. per day. The locations were selected after consideration of the critical economic factors: raw material supply, labor, water, and existing transportation facilities. Final product costs were debited with transportation charges to reflect product distribution in a common market.

The designs were developed on a conservative basis. Known processes of definite operability were utilized to the fullest extent. When proved processes were not available, the results of research were employed to devise a process with maximum assurance of operability.

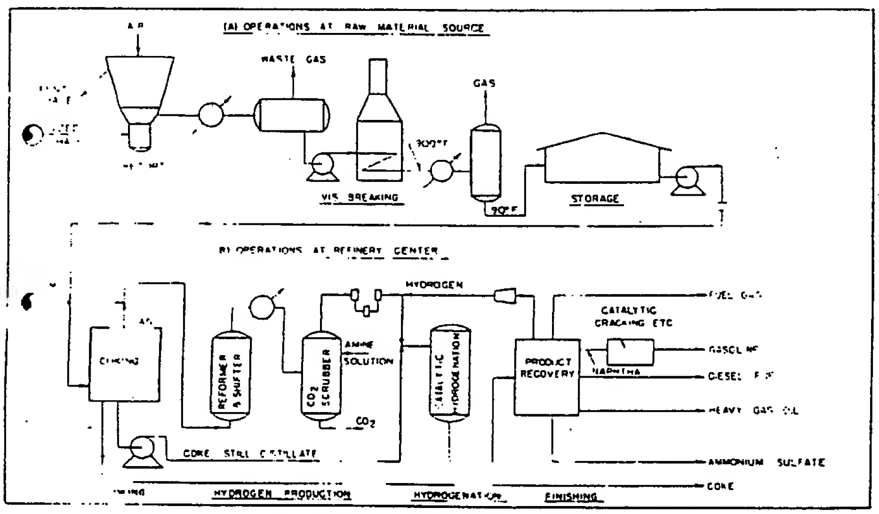

Fig. 1—Liquid fuels from oil shale

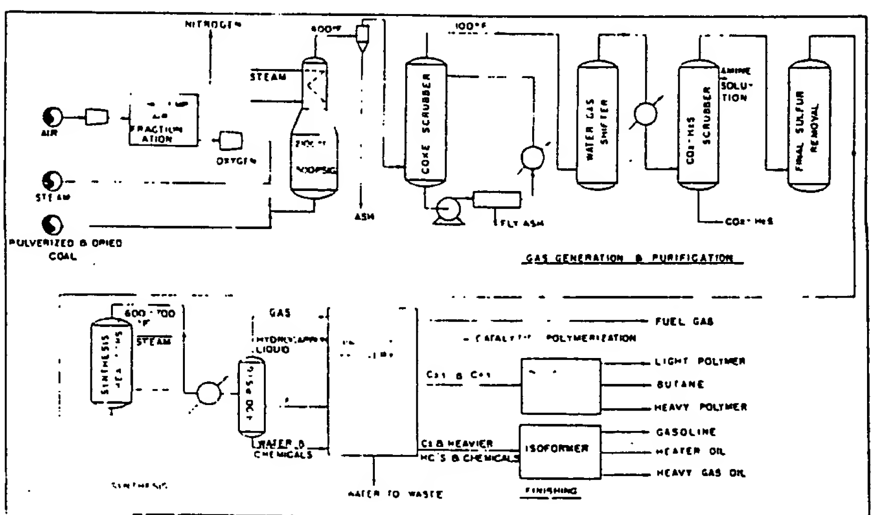

Fig. 2—Synthetic fuels from coal

Oil Shale

It has been estimated that at least 100 billion barrels of oil can be obtained from known United States shale deposits.[1] The recovery of oil from shale is a commendable conservation measure since oil shales in their natural state are not useful

 

GEORGE ROBERTS   P. R. SCHULTZ

This paper summarizes the results of a study of the technical and economic status of liquid fuels from oil shale and coal. This study was made to bring up to date evaluations of these raw materials as potential replacements for crude petroleum. Roberts is manager of research department and Schultz is manager of economics department, Stanolind Oil & Gas Co., Tulsa.

as fuels like coal and natural gas.

Production of liquid fuels from oil shale may be divided into two basic operations: (1) the mining of the shale and recovery of the crude shale oil and (2) refining of the crude oil. In the United States, the Bureau of Mines is actively investigating all phases of the operations. Some industrial concerns are studying the retorting operation and refining of the crude oil.

The investigations on mining by the Bureau of Mines at Rifle, Colo., have indicated that oil shale in that region can be mined at a cost of about 60 cents per ton by "underground quarry" techniques.[2] Conventional conveying equipment can be used to transport the shale to the nearby retorting site.

For the retorting of oil shale, several methods have been proposed, and some experimental work has been performed. The methods include N.T.U. retorts, fluid bed operations, Thermofor kiln, and Union Oil Co.'s upflow retort.[3] The Union type was selected as a basis for this study since it is continuous in operation, relatively simple, and requires a minimum of cooling water. It is a large cylindrical vessel into which the crushed shale is introduced by an under feed stoker device. The shale passes upward through the vessel and is discharged as ash at the top. Air enters at the top, is preheated by the effluent ash, burns the residual coke in the spent shale, and carries heat into the raw shale for removing the crude shale oil. The vapors from the distillation zone are cooled while heating the incoming shale, and the make gas and condensed oil are withdrawn near the bottom of the vessel.

Refining of the crude shale oil into products competitive with those from petroleum is a major problem. The shale oil is rich in olefinic and ring compounds and has troublesome con-

TABLE 1—RAW MATERIAL REQUIREMENTS AND PRODUCTS

	Wyoming crude	Natural gas	Oil shale	Indiana bituminous coal	Montana subbituminous coal
Raw material required per barrel of liquid product:					
Crude oil, bbl.	1.22		....	. .	....
Natural gas, M.c.f.	....	11.0	....	. . .	....
Oil shale, tons (30 gal. per ton assay)			1.80	....	....
Coal, tons			....	0.86	0.90
Liquid-product distribution, per cent:					
Gasoline	[illegible]	[illegible]	46.3	91.4	91.4
Gas oil	[illegible]	[illegible]	49.2	3.3	3.3
Residual fuel	[illegible]	[illegible]	4.5	5.3	5.3
Total	100.0	100.0	100.0	100.0	100.0
Byproducts produced per barrel of liquid product:					
Petroleum coke, bbl. (fuel-oil equivalent)*	0.11		0.09	...	
Net fuel gas, bbl. (fuel-oil equivalent)*		....	....	0.68	
Coal fines, tons		....	....	0.10	0.15

*Based on fuel oil having 150,000 B.t.u. per gallon net heat of combustion.

TABLE 2—INVESTMENT (DOLLARS PER BARREL PER CALENDAR DAY) OF EQUIVALENT GASOLINE

	Raw material				
	Wyoming crude	Gulf Coast natural gas	Colorado oil shale	Indiana bituminous coal	Montana subbituminous coal
Producing or mining	*$6,800	*$300	$1,100	$1,200	$1,100
Raw-material transportation	....	400	1,000	100	2,800
Processing	2,700	5,500	8,200	11,200	11,200
Product transportation	......	.....	.. ...	200	800
Operating investment	$9,500	$6,200	$10,300	$12,700	$15,900
Housing	....	. .	1,400	1,200	2,300
Total investment	$9,500	$6,200	$11,700	$13,900	$18,200

*All exploration costs, dry-hole expenses, etc., are charged against crude-oil operations without apportionment to natural-gas operations.

TABLE 3—RAW-MATERIAL COST (OR PRICE) AT MINE OR WELL HEAD

160/dag 12000 $ 1000 ~~[illegible]~~ 30t/m
6
360 · 72000 $

Raw material—	Unit price	Direct costs	Direct costs plus 6%/yr. on mining investment for depreciation and interest	Direct costs plus 14%/yr. on mining investment (10-year payoff after income taxes)
Wyoming crude	$/bbl.			*2.09
Gulf Coast natural gas	c/M.c.f.	....	....	*12.00
Colorado oil shale	$/ton	....	....	0.99
Indiana bituminous coal	$/ton	0.80	0.88	3.03
Montana subbituminous coal	$/ton	2.54	2.75	1.83
		1.39	1.58	

*Market price assumed.

TABLE 4—COST OF LIQUID FUELS EXPRESSED AS CENTS PER GALLON OF EQUIVALENT GASOLINE

	Wyoming crude	Natural gas	Oil shale	Indiana bituminous coal	Montana subbituminous coal
Direct costs:					
Raw material	*6.8	*3.3	4.1	5.4	3.1
Raw-material transportation	1.4	0	1.8	0.1	0.8
Processing	2.8	4.2	7.0	7.9	7.9
Product transportation	0	2.1	0	0.1	0.4
Subtotal	11.0	9.6	12.9	13.5	12.2
Less byproduct credits	1.3	0	0.5	3.2	0.3
Total direct cost	9.7	9.6	12.4	10.3	11.9
Direct costs plus 6 per cent per year on investment for depreciation and interest	†~~10.7~~	†11.9	16.4	15.3	18.1
Direct costs plus 14 per cent per year on investment (10-year payoff after income taxes)	†12.2	†15.0	22.5	22.5	27.6

*Based on market price. †Does not include charges on investment for raw-material production facilities.

TABLE 5—COMPARATIVE ESTIMATES OF LIQUID FUEL COSTS

Raw material	Natural gas		Oil shale		Bituminous coal	
Source	Gulf Coast		Colorado		East of Mississippi River	
Company	Standard-Stanolind	Standard Oil Dev. Co.*	Standard-Stanolind	Standard Oil Dev. Co.*	Standard-Stanolind	Standard Oil Dev. Co.*
Market	Midwest	East Coast	Midwest	California	Midwest	East Coast
Investment per barrel of total product per CD (including raw material and transportation)	$6,000	$7,100	$9,700	$8,600	$13,300	$9,600
Raw-material cost	12c/MSCF		$0.90/T		$3.03/T	
Gasoline cost (including 15 per cent charges on investment):						
Raw material, cents per gallon	3.3	3.0	5.1	4.7	6.5	3.7
Manufacturing and transportation less credits, cents per gallon	12.7	10.0	17.4	14.0	16.0	16.0
Total at market center, cents per gallon	15.0	13.0	22.5	18.7	22.5	19.7

*Data from paper by Murphree, Gohr, and Barr, A.I.Ch.E. regional meeting, Tulsa, May 9, 1949.

tents of nitrogen, sulfur, and oxygen.[4] It is also too deficient in hydrogen to respond well to cracking. However, a preliminary coking operation can remove some sulfur with the coke, and the coke still distillate can be hydrogenated to yield a product that is amendable to finishing by conventional methods.[5]

The flow for the shale oil processing is illustrated diagrammatically in Fig. 1. Oil shale, assaying 30 gal. of "oil" per ton, is assumed to be mined in the region near Rifle using the techniques developed by the Bureau of Mines. After crushing at the mine, it is transported by conveyor to a nearby retorting site where the oil content is recovered in Union-type upflow retorts. The crude shale oil is vis-broken in order to reduce pour point and viscosity sufficiently to permit pipe-line transportation to a refinery near its [illegible]tial market (in this study considered to be Chicago). Extensive refining near the shale-oil deposits would be impractical because of the unavailability of labor and lack of adequate water supplies.

At the refinery at Chicago the vis-broken shale oil is subjected to a preliminary coking operation. The coke still distillate is hydrogenated catalytically, and the resulting product is finished into marketable fuels by conventional refinery techniques. Hydrogen for the hydrogenation operation is obtained by reforming and water-gas shift conversions of the fuel gas produced from the [illegible] and other units.

Process yields and costs associated with recovery and refining [illegible] oil are discussed under the heading "Economic Comparisons."

Coal

For the long-term future, [illegible] most important raw material [illegible] thetic fuels. Although the [illegible] States coal reserves are probably [illegible] less than the estimate prepared [illegible] the U. S. Geological Survey in [illegible] there are undoubtedly tremendous quantities existent. This is particularly true of the lower rank western coals, subbituminous and lignite. Because of their location and their

physical properties, these two grades of coal find little demand today. Certain grades of eastern coal, such as anthracite and the bituminous grade suitable for making metallurgical coke, can be exempted from use for synthetic-fuel production because of their scarcity.

Synthetic liquid fuels can be produced from coal by either the Bergius hydrogenation process or the Fischer-Tropsch synthesis reaction. The data on recent developments in coal hydrogenation are confined, primarily, to publications of the Bureau of Mines.[6] There has been little published in recent years regarding the work of private industry in this field. Indications are that hydrogenation is somewhat less economic than the Fischer-Tropsch process. Consequently, this discussion will not include coal hydrogenation as a competitive alternate process.

The Fischer-[illegible] plicable to either [illegible] natural gas as raw material [illegible] fundamental [illegible] tion of the raw [illegible] thesis gas consisting [illegible] carbon monoxide [illegible] (2) reaction of [illegible] catalyst [illegible] synthesis gas [illegible] mally [illegible] oxide ratio [illegible] their [illegible] [illegible]

fiers. The Bureau of Mines is investigating two types of dilute-phase reactors, the simple vortex burner and the Koppers generator. Other groups are investigating fluid-bed carbonization of coal to yield fuel gas and fluid-bed gasification of coal or coke to produce synthesis feed gas. All of these are alternate methods to obtain reaction of coal or coke with oxygen and superheated steam yielding carbon monoxide and hydrogen as primary products.

German commercial practice has been based entirely on low H_2:CO ratio gas made from coal or coke. The synthesis process typically uses a cobalt-thoria catalyst in fixed beds, with the heat of reaction removed by oil or water circulating through a multitude of tubes traversing the catalyst beds. The chief disadvantages of the German process are (1) low-pressure operation which necessitated large reactor volumes, (2) use of expensive cobalt-thoria catalyst, (3) poor heat removal because of the fixed beds, and (4) the production of heavy saturated hydrocarbons having low value as motor fuel.

[illegible] work on synthesis [illegible] gas has been carried [illegible] by the Bureau of Mines. In their work, two types of [illegible] tested experimentally [illegible] catalyst. In the [illegible] type, the catalyst [illegible] fixed bed [illegible] through the [illegible]

tives, with some waste carbon dioxide and water. The hydrocarbons are recovered by conventional methods. After catalytic treatment under mild cracking conditions (isoforming) which also converts the accompanying oxygenated compounds to olefins, these hydrocarbons are separated into gasoline, distillate fuel, and residual fuel. This synthesis process is conducted at pressures up to 500 psi., has vastly improved heat transfer characteristics as compared to fixed-bed processes, utilizes a cheap catalyst, and produces a high yield of quality gasoline.

Very little work has been done to date on application of fluid-type reactors to low H_2:CO ratio gas, such as may be obtained from coal gasification. Since the fluid-type reactor is considered superior to the fixed bed for this reaction, it was employed for purposes of this study. As a consequence, the water-gas shift to obtain higher ratio gas was included in the process design and the economics.

Recovery and finishing of the products from the synthesis reaction based on gas from coal have not been intensively investigated in this country. However, the operations developed in connection with synthesis from natural gas should be directly applicable.

The basic process flow for the coal plants is illustrated in Fig. 2, although separate designs were made for the bituminous and subbituminous coal cases. The coal, mined and delivered to the plant site, is pulverized and reacted in a fluid bed with oxygen and steam at elevated pressure. The resultant gas has a H_2:CO ratio of approximately 0.8 and is reacted with steam over a water-gas shift catalyst to yield a H_2:CO ratio of 1.8. After removal of carbon dioxide and sulfur compounds, the process flow is similar to that developed for a plant using natural gas. The synthesis gas is reacted over a fluid iron catalyst, and the reaction products are separated. A portion of the off gas is recycled to the reactor while the net make is passed through a conventional oil absorption system to recover the liquid hydrocarbons. The liquid fraction, combined with the debutanized stream from the vapor recovery system, is isoformed to improve octane rating and to convert the oxygenated compounds to the corresponding olefins, and is fractionated into conventional cuts. The propylene and butylene recovered in the absorption system are catalytically polymerized to yield polymer gasoline.

Since this study is concentrated on liquid fuels, neglecting byproduct chemicals, the product water from the reactor is subjected to distillation to concentrate the water-soluble chemicals as a distillate. This fraction is passed through the isoformer to convert the oxygenated materials into olefins and augment the hydrocarbon yields.

Economic Comparisons

A study of the economics of liquid fuels from coal and oil shale would have little meaning without an index for comparison. Consequently, a base case for fuels from Wyoming heavy crude was developed. This oil was chosen as the least desirable of current crudes and the first increment of crude production which could be replaced by other sources of liquid fuels. A case utilizing Gulf Coast natural gas as a synthesis raw material was also developed.

In evaluating these various raw materials as sources for liquid fuels, a number of important factors must be considered. Transportation charges are important in the costs of the finished product, and it was elected to develop cost data for all cases on the basis of a market centered at Chicago.

Choice of raw-material source is likewise of considerable economic significance and was carefully made. Selection of a source of oil shale falls rather obviously to the region near Rifle with the shale-oil refinery located at Chicago as previously men-

tioned. For the bituminous coal case, a location near Vincennes, Ind., was chosen as combining adequate coal deposits, water, suitable labor supply, and rail-transportation facilities. In the case of subbituminous coal, however, selection of a plant site was not so easy, and it was finally necessary to compromise on a location near Miles City, Mont. Water, labor supply, and rail facilities are adequate at this location, but the coal must be brought to the site by means of a 60-mile conveyor system.

From the standpoint of process design, the principal difference between the subbituminous and bituminous cases is the disposition of make (fuel) gas in excess of plant requirements. In the bituminous coal case, it is assumed that this gas could be marketed in the immediate area (southern Indiana) as industrial fuel. In the subbituminous coal case, no market disposal appeared feasible, so the excess is returned to the synthesis gas generator for reconversion to carbon monoxide and hydrogen. This procedure decreases the coal requirements per barrel of liquid products but does involve reprocessing of synthesized hydrocarbon gases. Another difference in these two cases is that the bituminous-coal case contemplates underground mining while the subbituminous coal case employs strip mining.

Summary Material Balances

Summary material balances for all cases are given in Table 1. It may be noted that the coal requirements per barrel of liquid product are virtually the same for bituminous and subbituminous coal. However, the bituminous coal has a net production of byproduct fuel gas amounting to 0.68 bbl. of fuel-oil equivalent. The subbituminous-coal case is in fuel balance and does not have this by-product.

Cost estimates were made for each of these designs based on high engineering standards. All utilities and facilities in addition to process equipment were included. In this connection, useful indices were obtained from the definitive cost estimates prepared for the Stanolind Hugoton project for synthesis of liquid fuels from natural gas. Where applicable, raw-material mining and transportation investments were included. Product-transportation investments necessary to serve a common marketing area were also estimated.

Investment costs.—A comparison is given in Table 2. These costs are expressed in dollars per daily barrel of equivalent gasoline. Equivalent gasoline is defined as 100 per cent of the gasoline yield plus 70 per cent of the distillate fuels, plus 40 per cent of the residual fuel. This method adjusts different products to a comparable basis

The investment costs for Wyoming crude and natural gas include the producing facilities. The large difference shown in this item ($6,800 per daily barrel vs. $300) is caused by the apportionment of exploration costs, dry-hole expenses, etc., which are normally charged entirely to crude-petroleum operations. Also, the drilling and gathering charges for natural gas are minimized because of the large deliverability of individual wells in the Gulf Coast area. These items of investment are shown for comparative purposes but were not used in the preparation of final product costs since crude and natural gas were assumed to have been purchased at a market price.

Raw-material costs.—The comparative costs are given in Table 3. In the costs for shale and coal, all items of expense including management, overhead, royalties, and production and property taxes were considered. The price of $2.09 per barrel for Wyoming crude is based on a posted price of $2.04 for 28 A.P.I. gravity and a gathering charge of $0.05 per barrel. The price of 12 cents per 1,000 cu. ft. for natural gas is representative of the average price which might be obtained under a long-term contract for Gulf Coast natural gas gathered to a

central point. Although the Bureau of Mines estimate for shale mining amounted to 60 cents per ton, this study yielded 80 cents per ton direct cost and 99 cents per ton with 14 per cent charges on investment.

Estimated costs of liquid fuels.—These, as derived from the raw materials discussed, are shown in terms of equivalent gasoline in Table 4. It will be noted that direct costs are separated into several categories. The raw material cost was obtained from the values shown in Table 3. Raw material transportation includes the cost of moving the raw material from a central point at the source to the processing site. For the oil-shale case, however, the cost of transporting the vis-broken shale oil via pipe line from the retorting site at Rifle to the refinery site at Chicago was included under raw material transportation. Likewise, the raw-material transportation charge for Wyoming crude covers delivery of crude oil via pipe line to a Chicago refinery. In the natural-gas and coal cases, product-transportation costs to the marketing area are included. The byproduct credits include such items as excess fuel gas, petroleum coke, and coal fines.

Charges for depreciation plus interest or return on the investment must be included to ascertain the true competitive relationship betwee these sources of liquid fuels. Capita charges at 6 per cent per year (4 pe cent depreciation and 2 per cent in terest on the borrowed capital) rep resent a return of investment bu nonprofit operation over 25 years. A 14 per cent per year, the profits afte income taxes would pay off the in vestment in about 10 years. It wil be noted that the addition of capita charges to the direct costs for coa and shale places the total cost fa above the level for Wyoming crud and natural gas. On the other hand synthetic products from natural ga can compete today with products fron purchased crude if the competitiv marketing area is judiciously selected

The foregoing discussion is all base on the current technological statu of synthetic fuels from coal and shale Present synthesis developments indicate that several phases of the processes are subject to much improvement. Although it is difficult to evaluate quantitatively the effect of possible improvement on the cost o synthetic fuels, such a computation is desirable to indicate the probable benefits to be derived from future research work. Several process improvements in coal synthesis, such as use of lower H_2:CO ratio and improved methods of coal gasification, are believed to have an even chance of accomplishment. If all of these improvements can be realized, the cost of equivalent gasoline from Indiana bituminous coal could be reduced from 22.5 to 17 cents per gallon. These costs should be compared with 12.2 cents per gallon for equivalent gasoline from Wyoming crude. Reductions are also possible in the costs of manufacturing liquid fuels from oil shale.

Numerous other estimates of the costs of liquid fuels from sources other than petroleum have been published. Bureau of Mines spokesmen' have quoted investments of $3,100 per daily barrel of capacity from oil shale, $5,300 per daily barrel from natural gas, and $8,600 per daily barrel from coal (including mining). Direct comparison of most previously published estimates with those obtained in this study is impossible because the basis and scope of these estimates were not given or were not detailed. However, the results of a similar study by Standard Oil Development Co. were given' in sufficient detail to permit a comparison as indicated in Table 5. These data have been adjusted to a common raw-material cost, but charges in investment were unchanged because Standard Oil Development Co. used 15 per cent while, in this study, 1 per cent ad valorem tax had been included in manufacturing costs prior to addition of 14 per cent charges on investment.

For the natural-gas cases, the dif-

ferences in manufacturing and transportation costs may be due to a combination of the transportation charges to different markets and the crediting of byproducts. For the oil-shale cases, a similar discrepancy may be due, in part, to the same factors.

The bituminous coal estimates show a marked difference in raw material costs. The Stanolind case has a low liquid-product yield. However, it consequently produces a large quantity of byproduct gas which, as a credit, reduces the manufacturing costs. Some portion of the 2.8 cents per gallon difference is attributable to the inefficiency of the Stanolind case introduced by conversion of generator gas to a higher H_2:CO ratio.

In general, the agreement between these estimates is considered to be quite good. The fact that Stanolind estimates are consistently high reflects the basic conservative premise that the designs would incorporate proved processes with a minimum reliance on untested technological improvements. As was previously mentioned, eventual validation of some of these probabilities could reduce the estimated cost of synthetic gasoline from coal from 22.5 to 17 cents per gallon.

In summary, the production of liquid fuels from oil shale or coal is in an immature state of technical development. It can be expected that continued research will result in process improvements which will effect significant reductions in the investments, operating costs, and raw material requirements involved in synthetic liquid-fuels manufacture.

From the standpoint of economics, this study shows that, at present, liquid fuels from oil shale and coal cannot compete with those derived from crude petroleum. Natural gas as a raw material may or may not be competitive, depending on the relative locations of raw material supply and product markets.

Based only on present technological status and estimated products costs, a choice between coal and oil shale as alternate raw materials for liquid fuels production cannot be made. Future research on these processes, however, should indicate which process is superior.

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BOOKS

THE PETROLEUM CHEMICALS INDUSTRY. By Richard Frank Goldstein. With a foreword by Prof. Sir Robert Robinson. Published by E. & F. N. Spon, Ltd. 57 Haymarket, S.W.1, London, England. [illegible] pp. £3 3s.

This book has been especially compiled for all those interested in petroleum and its products, in catalysis and catalytic processes, in industrial solvents, and in all branches of the organic chemical industry, particularly those concerned with aliphatic chemicals: for the manufacturer, user, the industrial chemist, chemical consultant and chemical engineer, and in the academic sphere, for both teaching staff and student. Both principle and practice are dealt with and the treatment of the subject matter is comprehensive, ranging from fundamental chemical theory to the application and outlet for the finished product, a consideration which makes it of value also to those responsible for technical and commercial development.

The book is divided into 20 chapters from "The Sources of Petroleum Hydrocarbons" to "Chemical Byproducts of Petroleum Refining," those in between having such headings as Oxidation of Paraffins; Manufacture of Olefins; Acids, Anhydrides, and Esters, etc. Three appendices deal with routes to petroleum chemicals, statistics of production and consumption of petroleum, and statistics of United States production of synthetic organic chemicals of non-coal-tar origin.

"That's a lotta baloney · bulls ain't attracted by a red shirt like I got on!"

, Sweden,

August 2, 1951.

Mr. Boyd Guthrie, Chief
Oil-Shale Demonstration Branch,
United States Department of the Interior
Bureau of Mines,
Box 792,
R i f l e, Colorado.
U.S.A.

Dear Boyd Guthrie:

Thank you for your letter dated July 24 pertaining to the cooperate program presently on schedule.

I myself and in fact all of us had hoped that you or Simon Klosky would have a chance to visit Sweden in order to witness the final part of the test runs. Of course, Mr. Robert Beverly is very welcome and we will not hesitate to present him all details and figures demanded. We believe that the test runs pending will be of decisive importance for a comprehensive evaluation of our methods. Therefore, we hope that you will have a chance to participate at least in the final stage of the tests and would appreciate if you later on would investigate the possibility. Anyway, the preliminary research work will take some time and would hardly demand the presence of your observers. We have to compile several sets of heat balances before we are ready to go into action.

Our research department and our associates are already involved in preparation work. Your gas combustion retort presents fine efficiency figures and your present retort to be designed with a bed area of 60 square feet and an anticipated capacity of 300 tons per day is really something.

In order to establish a smooth road of operation we will within shortly arrange for a test run schedule with the different phases timed and specified. This schedule will be submitted you and all arrangements for the American expert's visit to Sweden will be prop r-ly taken care of.

Kindly accept our thanks for your report regarding the shale shipped to us. Your method of sampling seems to guarantee a representative sample of the Mahogany ledge material. Incidentally, it would be extremely interesting to discuss with you the possibility of combining in the Mahogany ledge the destructive methods with the Ljungström pr cess.

A copy of this letter is sent to Mr. C.A. Norgr n.

Yours very truly,

Kopia till Dir. Gejrot,
Dir. G.E.Anderson,
Dir. David Dalin,
Prof. [illegible]

Till Bolagsledningen.

PM

betr. Bradford- och Canada-projektet.

I januari 1948 uppdrogs åt mig att studera förutsättningarna för tillämpningen av Ljungströmsmetoden på oljesand i U.S.A., företrädesvis i Bradford, Pa. Av ing. Olle Ljungström erhöll jag dels ett antal prover av oljesand, dels en hel del data av intresse.

Efter att ha företagit de laboratorieundersökningar, som de erhållna proverna gav anledning till och efter att ha genomräknat såväl de tekniska som de ekonomiska förutsättningarna kom jag fram till en uppfattning om projektets möjligheter, som jag framlade i ett antal rapporter och promemorior (OS-5 m.fl.) samt vid de konferenser, som ha hållits tid efter annan i frågan. Min uppfattning, som jag efterhand fått alltmera bestyrkt genom de data om oljesanden, som tid efter annan publiceras i fackpressen, var, att projektet ang Bradfordsanden var "dödfött". Jag vill bara påminna om några fakta, vilkas innebörd kanske bäst framgår vid jämförelse med motsvarande för Lj-anläggningen i Norrtorp:

	Norrtorp	Bradford
Oljehalt i lagret	ca. 15 volyms-%	4 volyms-%
Lagertjocklek	16 meter	15 meter
Borrdjup	25 meter	300-500 meter
Kraftpris	(1,3 öre/kWh)	(0,9 cts/kWh)

För jämförelses skull bör naturligtvis nämnas, att man i Bradford blott skulle värma berget 40-60°C mot i Norrtorp 380°C.

Redan de anförda siffrorna ger anledning till betänkligheter i fråga om projektets framtid. Därtill må fogas, att en grundlig teoretisk utredning av strömningsförhållandena i porösa kroppar, som jag gjort, (och som kommer att publiceras i Acta Polytecnica) visar, att det är högst osäkert om en temperaturhöjning av denna storlek kommer att höja oljeutbytet över vad som kan åstadkommas genom vanlig vattenspolning ("secondary recovery").

På grund av det synnerligen stora intresse, som amerikanska oljekretsar visat för detta uppslag har det ansetts lämpligt att, trots betänkligheterna, ev. utföra ett fältförsök i Bradford för att få ett definitivt svar på frågan om Lj-metodens möjligheter. Ett förslag till fältförsök har därför utarbetats av ing. Olle Ljungström och mig. (OS-12). Detta förslag har översänts till Bradford och är där nu under granskning.

Förslaget utformades försiktigt med tanke på ovan anförda betänkligheter. Den senaste korrespondensen från U.S.A. visar emellertid att detta icke observerats av de amerikanska intressenterna, en följd, som jag fruktar kan få vissa konsekvenser. De förhoppningar, som väckts till liv under ing. Ljungströms besök i Bradford, kommer med all säkerhet icke att infrias, om ett fältförsök utföres där. Den förhands-"goodwill", som nu finnes för Lj-metoden såväl i U.S.A. som i andra länder, skulle helt spolieras av ett fältförsök med negativ utgång. Detta skulle vara till stor nackdel för S.S.A.B., ty Lj-metoden har helt säkert stora möjligheter på andra fyndigheter. En "spelöppning" på den utländska marknaden bör ske på en gynnsam plats, helst på den gynnsammaste, som kan uppletas, och i varje fall icke på en så ogynnsam plats som Bradford.

Under en av de tidigare konferenserna i detta ämne framförde jag förslaget att man borde ägna intresse åt Canadas oljesand- och skifferförekomster. De litteraturstudier, som jag gjort häröver (OS-1) har bekräftat att möjligheterna här är större. Det är ett helt annat material än Bradfordsanden, som är tillfinnandes i Canada. I stället för "oljesand" borde man här använda termen "bituminös sand". Här gäller det icke att öka framrinningen av kapillärt bunden olja, utan i stället att genom en mild upphettning (till ca. 100°C) kemiskt förändra bitumenet, så att en lättflytande olja erhålles. Mängden utvinnbar olja varierar, men uppgår ofta till ca. 30 volyms-%. Topografin är sådan, att stora fyndigheter kunna uppletas, där borrdjupet är ringa.

De tekniska förutsättningarna är sålunda goda. Däremot kan man möjligen hysa någon tvekan om de ekonomiska möjligheterna i Canada just nu, med tanke på de stora mängder fri olja, som under det senaste året upptäckts i samma delar av landet, där också sanden finns. Det synes emellertid av fackpressen att döma vara så, att den bituminösa sanden fortfarande är aktuell. Tidigare har mycket pengar satsats på Max Balls varm-vatten-process, men utan framgång. Nu har man börjat försöka andra metoder. I Chem. Eng. News lästes den 30 jan. i år en notis, som omtalade, att den s.k. "fluid-solid"metoden lagts till grund för en pilot plant, för bearbetning av Alberta-sand.

Ett annat faktum, som må noteras i detta sammanhang är följande: I samband med produktionen av olja i de nya, stora oljefälten erhålles stora kvantiteter naturgas. För transporten av oljan till avsättningsområdena har man redan satt igång att bygga en pipe-line från Alberta (Edmonton) till Lake Superior. Gasen kan man däremot ej få avsättning för. Att bygga en gasledning är otänkbart och den lokala industrin är fortfarande alltför obetydlig för att kunna konsumera dessa gaskvantiteter. Utnyttjandet av gasen är därför oljeproducenternas stora bekymmer just nu. Läget kan illustreras med några produktionssiffror för de två år under vilka oljerushen pågått. (Siffrorna hämtade ur Petroleum Times den 10 februari 1950.).

	Alberta		Hela Canada	
	1948	1949	1948	1949
Total prod. av naturgas m.cu.ft.	49,o milj.	65,9 mil.	58,6 milj.	74,9 milj.
Värde,milj. $	6,96	3,30	15,63	9,92
Gaspris, cts/m.cu.ft.	14,2	5	26,6	13,2

Gaspriset har sålunda i Alberta sjunkit från 14 till 5 cts/m.cu.ft. på ett år.

Denna utveckling bidrager till möjligheterna att bearbeta Athabasca-sanden. Det bör nämligen ligga nära till hands att använda denna billiga gas som bränsle i ett ångkraftverk, som genererar den för Lj-metoden behövliga el.-energin. Via ångkraftverk + Lj-anläggning skulle sålunda all överskottsgasen från oljefälten bekvämt kunna omvandlas i olja som ju kan transporteras i rörledningen.

Om det sålunda finns all anledning att frångå Bradford-projektet, så finns det lika stor anledning att arbeta på Athabasca-projektet. (Canada är f.ö. en lämplig inkörsport även betr. metodens användning på oljeskiffer. Oljeskiffern i New Brunswich och Nova Scotia börjar bli aktuell).

För att onödig tid ej skall förspillas, föreslår jag därför att arbetet på Canada-projektet intensifieras. Jag vill ingalunda underskatta värdet av att ha Mr. Hans Lundberg som kontaktman, men jag tror, att det bör gå att få fram saken fortare, eftersom ju det hela ändå är en bisyssla för Mr. Lundberg. Jag anser att en direkt kontakt med canadensiska myndigheter och sakkunniga (t.ex. Canadien Geological Survey) skulle vara av stort värde. Mycket av värde skulle säkerligen även stå att vinna genom direkt personlig kontakt.

Då jag ända sedan den dag, då Amerika-projektet började diskuteras, fått mig anförtrott uppgiften att göra de erforderliga experimentella, tekniska och ekonomiska utredningarna, och därvid hunnit bli väl förtrogen med situationen har jag ansett mig böra på detta sätt framlägga de synpunkter och förslag, som jag anser vara bäst förenliga med vårt företags bästa.

Norrtorp den 27.2.50.

Gösta Salomonsson

beträffande den elektrotermiska oljeframställningsmetodens tillämpning i U.S.A. och frågor i samband därmed.

Vid sammanträde den 1 mars mellan direktör Gejrot, dr. Ljungström, direktör Wiborgh, övering. Johansson, civiling. Söderbaum och undertecknad diskuterades de frågor och problemställningar, som kunde tänkas bli aktuella vid tillämpning av "Ljungströmsmetoden" på amerikanska förhållanden. Som resultat av diskussionen beslöts, att de pågående utredningarna skulle fortsättas och att i första hand följande två alternativ skulle undersökas närmare:

a) möjligheten använda kvarblivande skifferkoksberg som ackumulator för naturgas.

b) avdrivning av oljan ur "oil sand" på elektrotermisk väg.

Nedan lämnades dels en sammanfattning av de synpunkter, som framkommo vid diskussionen, och dels några orienterande beräkningar, som utförts med ledning av hittills tillgängliga data.

I Gasackumulatorproblemet.

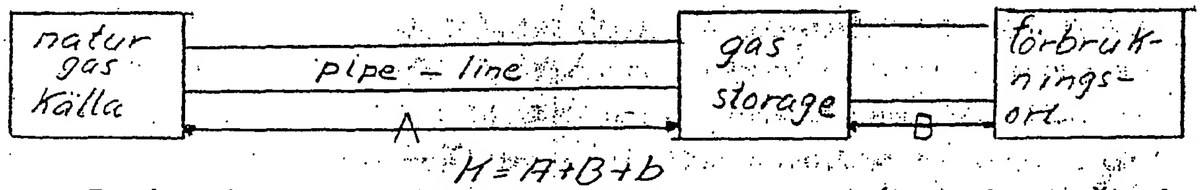
I U.S.A. utgöres en icke obetydlig del av bränsletillgångarna av naturgas. Ehuru mycket bekväm i användningen erbjuder naturgasen vid tillgodogörandet vissa problem i samband med dess transport och lagring. Förbrukningen av gas för såväl hushålls- som industribruk fluktuerar starkt, dels under dygnets olika timmar, dels under de olika årstiderna.

Gasen distribueras från källan till förbrukningsorten genom "pipe-lines" ofta av mycket ansenlig längd. För att kunna möta toppbelastningarna måste man emellertid antingen dimensionera rörledningarna för maximalbehovet eller anordna utjämnande gasackumulatorer för förbrukningsorten. Åtminstone vid längre ledningar har man valt det senare alternativet. Som ackumulatorer användes gasklockor av högtrycks- eller lågtryckstyp. Deras i förhållande till kapaciteten höga anskaffningskostnad (jfr nedan) har emellertid i många fall lagt hinder i vägen för naturgasernas utnyttjande.

En annan möjlighet, som på en del orter använts för att ackumulera gas, är att utnyttja gamla, avverkade oljefält. Gas nedtryckes i de gamla borrhålen och lagras i den porösa bergmassan, som förut innehållit petroleum.

Vid elektrotermisk avdrivning av ett skifferfält erhålles som återstod en skifferkoksmassa som dels är hydrofob (vattenavvisande) dels har en aktiv yta, som i kallt tillstånd är i stånd att adsorbera stora mängder av bl.a. kolvätegaser. (jfr. bilaga 1). Det skulle därför kunna vara möjligt att utnyttja ett i närheten av en stad liggande skifferfält för två ändamål, nämligen dels tillgodogörande av olja och gas ur skiffern, dels det avdrivna skifferfältets utnyttjande som "gas storage" för naturgas.

För att en dylikkombination skall vara möjlig fordras alltså att i närheten av en stad, som skulle kunna ifrågakomma för naturgastillförsel finnes ett skifferfält, av sådan typ att oljeutvinning kan ifrågakomma. Förhållandena kunna återges med en skiss:



Totala anläggningskostnaden K för gasens transport (inkl. lagring) från a till c blir summan av kostnaderna för rörledningen A och rörledningen B samt kostnaden för gasackumulatorn b. Ledningen A dimensioneras för medelförbrukning av gas, medan ledningen B dimensioneras för maximalförbrukning. B blir alltså dyrare pr längdenhet och bör följaktligen göras så kort som möjligt. I det fall, att en gasklocka av vanlig typ bygges kan B göras praktiskt taget = 0.

I samma mån som gasackumulatorn kan erhållas billigare kan naturligtvis sträckan B få vara längre. Eller med andra ord: Ett lämpligt skifferfält kan utnyttjas som "gas storage" även om det ej ligger omedelbart intill staden.

De fördelar, som stå att vinna genom kombinationen skifferoljeframställning "gas storage" äro:

1) Naturgasens användningsmöjligheter ökas. Orter med skiffertillgångar i närheten kunna använda naturgas, även om avståndet till gaskällan är större än vad som tidigare ansetts ekonomiskt för gasdistribution. Genom att kostnaden b (jfr ovanst. ekvation) minskas, kan nämligen A få stiga, utan att den ekonomiska gränsen överskrides.

2) Nya möjligheter öppnas för tillgodogörandet av skifferförekomster som tidigare ansetts stå på gränsen till bearbetbarhet.

Teknisk utformning. Då skifferkoksens adsorptionsförmåga är av betydelse först vid temperaturer omkring 20-40°C, måste berget kylas ned till dessa temperaturer så snabbt som mjöligt. Detta bör kunna ske med naturgas som värmetransporterande medium. Samma rör, som användes för bortledande av pyrolysgaserna användes för nedpressning av gasen (i det [illegible] berget). De kvantiteter, som kunna nedpressas, få genast strömma tillbaka upp igen, medförande vissa kvantiteter värme. Gasen får via fältets vanliga kondensorer gå ut i gasdistributionsnätet. På detta sätt kan det svalnande bergets alltmer tilltagande gasackumuleringskapacitet börja utnyttjas, samtidigt som avkylningen påskyndas. För att erhålla en så stor kapacitet som möjligt bör man kunna förvara gasen under relativt högt tryck t.ex. 20 atm. Detta betyder, att för att tillfredsställande tätning mot läckage skall erhållas, måste skifferkoksen ligga på tillräckligt djup 50 meter under markytan eller mera. Detta villkor motverkas dock av kravet på låga borrnings- och rörkostnader. I varje särskilt fall får en avvägning göras mellan dessa två varandra motverkande faktorer.

Överslagsberäkning. De data och förutsättningar som skulle behövas för en genomräkning av det ovan behandlade projektet saknas, men för att erhålla en uppfattning om vilka storleksordningar det här rör sig om, kan man göra en överslagsräkning med ledning av siffror från svenska förhållanden.

Vi förutsätta att det avdrivna skifferfältet är av samma storlek som det hittills avdrivna Lj-fältet (Norrtorp II) pr m^3 skifferberg har därur erhållits ca 90 liter olja + 100 Nm^3 gas. Den koks som kvarstår efter avdrivningen av 1 m^3 skifferberg torde innehålla ca. 0,1 m^3 fri volym (i form av sprickor o.dyl.). Själva koksvolymen skulle alltså uppgå till 0,9 m^3. Sammanlagda gasvolymen som vid 20°C skulle kunna ackumuleras (i komprimerad och adsorberad form) i 1 m^3 skifferberg skulle då bli:

vid 10 atö: ca. 3,9 m^3 (20°C, 1 atm).

Som jämförelse kan nämnas, att vid större storlekar av gasklockor anläggningspriset är ca. 75 - 80 kr pr m^3 gasvolym.

Värdet av skifferfältet som gasackumulator skulle då bli:

vid 10 atö gastryck: ca. 290 kr/m^3

Obs! Detta höga värde har ett Lj-fält naturligtvis endast under så gynnsamma omständigheter, att det 100 %-igt kan utnyttjas som gasackumulator.

Med nuvarande storlek skulle Lj-fältet motsvara en gasklocka om ca. 2.000.000 m^3(20°, 1 atm) vid gastrycket 10 atö.

För att utjämna årsvariationerna i gasförbrukningen torde en gasackumulator i en normal stad behöva rymma ca. 1 månads genomsnittsförbrukning. Det nuvarande Lj-fältet skulle alltså kunna utjämna årsvariationerna inom ett distributionssystem med en dygnsförbrukning av ca. 70.000 m^3. Som jämförelse kan nämnas, att Örebro stads ungefärliga förbrukning är 25.000 m^3/dygn.

II. Oil-sand-problemet.

Problemet att med vattentryck o.dyl. metoder utvinna kvarvarande olja ur "oil-sand" torde vara så väl genomarbetat av amerikanska teknici, att möjligheterna på detta område torde vara uttömda. En möjlighet finnes, att på elektrotermisk väg uppvärma sanden så mycket, att oljans viskositet och ytspänning sänkes, vilket skulle underlätta oljans framrinning till pumphål. Emellertid är sanden så finkornig och följaktligen de kapillära krafterna så stora, att det förefaller föga sannolikt att en dylik sänkning av viskositet och ytspänning skulle kunna frigöra några avsevärda kvantiteter olja.

En annan möjlighet att utnyttja den elektrotermiska metoden består i att sanden upphettas till så hög temperatur (t.ex. ca.200°C) att en verklig destillation (ej pyrolys) av i sanden befintliga olja sker. För att avdriva

även de tyngre oljefraktionerna skulle man vid destillationen tillföra vatten (vattenångdestillation). Detta medför naturligtvis större värmeförbrukning, varför man måste undersöka i varje särskilt fall på vilken punkt destillationen skulle avbrytas, för att optimalt utbyt skulle erhållas.

En fördel med denna metod för bearbetning av oljesand är att även relativt djupt belägna "oil-sand"-förekomster bli åtkomliga för oljeutvinning. Största möjliga arbetsdjupet blir naturligtvis beroende på borrningskostnaderna och sandens oljehalt och mäktighet.

<u>Överslagsräkning.</u> En grov bild av energiförbrukningen för avdestillationen kan man erhålla genom jämförelse med skifferpyrolys. Oljehalten i oil-sand är varierande, men är ofta av samma storleksordning som i skiffer (5-6 %). Den mineraliska substansens specifika värme i sand och i skiffer är ungefär detsamma. I jämförelse med det värme, som åtgår för den mineraliska substansens temperaturstegring kan oljans ångbildningsvärme, resp. skifferpyrolysens reaktionsvärme försummas (i denna approximativa beräkning). Vid upphettning av skiffern till 400°C utvinnes ca. 2/3 av dess oljehalt och ungefär lika stor del av den i sanden inneslutna oljan torde avdestillera vid sandens upphettning till 200°C. Enligt resonemanget ovan skulle för sandens upphettning till 200°C åtgå ungefär hälften av det värme, som behövs för skifferns upphettning till 400°C.

Det har vid Lj-fältet visat sig, att energibehovet har uppgått till 5-6 kWh/liter olja. Vid oljeavdrivning ur oljesanden kan man alltså vänta sig en förbrukning av <u>2,5-3 kWh/liter</u> olja.

<u>Sammanfattning.</u>

Tänkbara möjligheter för Ljungströmsmetodens användning i U.S.A. äro:

a) för oljeutvinning ur skiffer.

b) för kombinationen oljeutvinning-"gas storage".

c) för avdrivning av restolja i "oil-sand".

<u>Aktuella frågor.</u>

För att man skall få en uppfattning om möjligheterna att realisera ovannämnda projekt måste de naturliga förutsättningarna undersökas. Detta innebär att följande frågor närmare behöva utredas:

1) <u>Förekomsten av oljeskiffrar</u> överhuvudtaget. Det är att förmoda att tillgängliga kartor o.dyl. över U.S.A:s oljeskiffrar ha utarbetats med hänsynstagande till möjligheterna att bearbeta skiffrar enligt tidigare kända metoder. Detta torde medfört att endast i dagen gående eller grunt liggande fyndigh t r beaktats. Den elektrotermiska in situ-metoden gör nu även skiffrar på större djup bearbetbara. Under förutsättning att borrkostnaderna ej bli för höga och att oljeutbytet pr borrhål (dvs. produkten av skifferlagrets mäktighet och oljehalt) är tillräckligt högt, böra skiffrar

av ända till 100, kanske 200 meters djup undermarkytan kunna bearbetas.

En uppfattning om dylika skifferförekomster bör lämpligen kunna erhållas av en geolog med erfarenhet på området (t.ex. från B.o.M.) Av intresse är sålunda både oljehalt, mäktighet och djup.

2) I synnerhet förekomsten av skiffrar i närheten av städer, där naturgastillförseln kan bli aktuell. Därvid bör ihågkommas, som ovan påpekats, att räjongen för distribution av naturgas från en gaskälla, kan bli avsevärt utökad genom kombinationen skifferfält-gas storage". Dessa skiffrar böra ligga på ej för litet djup och ej för långt bort från staden i fråga. Däremot är kravet på hög oljehalt ej fullt så strängt som vid övriga skiffrar.

3) Ett närmare studium av någon befintlig "pipe-line"för naturgas med tillhörande "gas storage" (helst av typen gammalt oljefält) skulle säkerligen vara av värde. Speciellt intresserar då fordringarna på och anordningarna vid en dylik gasackumulator, uppgifter om gasförluster i berget o.dyl.

4) Förekomsten av "oil-sands" som kunna vara lämpliga för elektrotermisk destillation. Även här bör den synpunkten beaktas, att också djupare liggande lager kunna bearbetas, om oljehalten och övriga faktorer äro gynnsamma.

Norrtorp den 9.3.1948

Gösta Salomonsson

Vidimeras:

D. Tenlin .... M. Andersson ....

VALUATION CONSULTANT
27 MAIN STREET
BRADFORD, PENNSYLVANIA

October 31, 1950

Svenska Skifferolje A. B.
Drottninggatan 5
Orebro, Sweden

Attention: [illegible] -President

Re: [illegible] Ljungstrom In-Situ Method

Gentlemen:

During the period [illegible] beginning September 10th and ending September 19th, 1950, the undersigned and seven additional technical and business experts from the United States of America were privileged to attend certain conferences in Sweden with technical and business experts representing your organization.

The above stated conferences were held through prior mutual agreement for the purpose of aiding interested parties in the United States to determine the feasibility for use of the above named Ljungstrom [illegible] Method, or Electrothermic Process, in the recovery of residual oil reserves from so-called depleted oil fields, such as may be found at, or near, Bradford, McKean County, Pennsylvania, and more particularly known as the "Bradford Oil Field".

The technical experts, who represented a local group of sponsors, have delivered their reports upon the results of their findings. It is the unanimous decision of the technical experts that the Ljungstrom In-Situ Method is uneconomical for use in the recovery of residual oil reserves in the Bradford Oil Field. The

cost of electric energy in the Bradford area at the present time, and in the forseeable future, is the most effective contributing cause of their decision.

The local group have also advised that they cannot be interested in the recovery of oil from more shallow oil and gas bearing formations or from shale in the United States and Canada through use of the Ljungstrom In-Situ Method, for the same reason that effects its use in the Bradford Oil Field.

You are to be complimented upon your gigantic operation in shale and the success which has been so earnestly achieved. Our best wishes are for your continued success.

During our visit in Sweden, and more particularly at the field demonstrations and technical and business conferences, we were afforded the privilege of acquiring your confidential information, even to the most minute detail. We have treated your information with the absolute confidence in which the same was reposed in us and [illegible] assured that we will continue to do so.

[illegible] decision is submitted with my deepest regret and I do want [illegible] to know that every possible consideration was given before the said decision was reached. In the event you are ever successful in finding a method whereby economic results may be obtained in the recovery of oil from residual reserves, I shall be pleased to aid in perfecting the same and perpetuating its use.

My sponsors and all who were privileged to attend the conferences and social functions in Sweden join in extending most sincere thanks for the interest you displayed in our problem and for your splendid cooperation.

Very truly yours,

Victor H. Samuelson

VHS/jt

A N A L Y T I C A L [illegible]

S V E N S K A   S K I F F E R O L J E   A. B.

The meeting in Sweden was the culmination of efforts extended by the Svenska Skifferolje Aktiebolaget of Orebro and Stockholm, Sweden, and Victor [illegible] Samuelson of Bradford, Pennsylvania, [illegible] relation to matters of technical import relative to the oil industry.

In Sweden, certain deposits of shale have been operated for the recovery of kerogen and its [illegible] about the year 1941 at Kvarntorp in the province of [illegible], the very [illegible] where the plants of Svenska Skifferolje [illegible] are now located. The stratum of shale is about 50 feet deep and the organic substances (kerogen) embedded therein varies from 5 to [illegible] percent by weight and yield about an equivalent percentage of oil. The shale deposits in the area would allow an extensive oil production for centuries to come, according to a published statement of the Swedish Shale Oil Company.

The shale oil industry in Sweden is of gigantic proportions and the operators must be [illegible] gratified upon the success which has been achieved by them. The industry [illegible] maintained for national reasons and for the same purposes as, for example, many of the stripper wells in America.

The Bradford Oil Field, which contains approximately 85,000 productive acres of oil and gas producing properties, is located principally in McKean County, in the State of Pennsylvania, and the

United States of America. The first producing oil well was discov-ered about the year 1871 and to December 31, 1949, a total of 523,852,446 barrels of oil had been recovered and produced from this field. A schedule entitled "Bradford Oil Field - Annual Crude Oil Production" is herewith enclosed for the purpose of showing the production of oil throughout the years.

The principal producing formation in the Bradford Oil Field is known as the "Bradford" or "Third Sand", being generally desig-nated as the "Third Bradford Sand". Its static aspects are porosity, permeability and saturation. At the present time, water flooding is the process employed to produce oil in the Bradford Field. This process is based upon the interplay of forces in the system sand-stone-oil-water.

The average Third Bradford Sand consists of a polyphase mixture of heterogeneous mineral grains, cemented to various degrees of compactness by other mineral compounds. Between grains are found interstitial voids (pores) which may be completely or partially fil-led by water or oil. The amount of these pore spaces constitutes the porosity of the sand. Oil saturation indicates the percentage of pores occupied by oil, whereas permeability is defined as "the ease with which fluids may traverse the (porous) medium under the influence of driving pressure."

Kerogen from shale and petroleum or crude oil from sand-stone are entirely different in composition and the methods hereto-fore used in the recovery of each have likewise been varied and different.

Four methods have been used in Sweden by Svenska Skifferolje A.B. for the recovery of organic substances, generally known as kerogen, from shale deposits. One of these methods, known as the Ljungstrom In-Situ Method, or Electrothermic Process, creates pyrolisis in the ground through use of electric energy as heat. It was hoped that this method would prove successful and economical in the recovery of residual oil reserves from the Bradford Third Sand and the conferences in Sweden were held for the prime purpose of determining the extent to which the use of the Ljungstrom In-Situ Method would prove beneficial.

As stated in my letter to the Svenska Skifferolje A. B., under date of July 7, 1947, a minimum of 400,000,000 barrels of residual oil remains in place in the Bradford Third Sand that cannot be recovered by present known methods. Competent authority has recently estimated these residual reserves to exceed 600,000,000 barrels of oil.

In the event a method can be found whereby any substantial percentage of the above stated residual oil reserves (600,000,000 barrels) can be recovered economically, a new oil field will, in effect, have been discovered. It is to this end that research has been going forward at an accelerated pace for several years past.

The foregoing explanation is given for the purpose of fully impressing upon the members of the Svenska Skifferolje A.B. our sincere desire and ambition to find a method whereby residual oil reserves may be recovered economically. We, of the Bradford group, are of the opinion that any method, having even the slightest chance of recovering residual oil reserves at a profit, must be investigated

and, if it is found that such a method can possibly yield satisfac-tory results in the forseeable future, such method should be exploit-ed to final determination.

It is natural that our first interest has been devoted to the recovery of residual oil from the local Bradford Oil Field, par-tially by reason of present investments in property, machinery and equipment and further due to the enormous wealth of data that has been accumulated throughout the years. Our investigation has, how-ever, included possibilities that may exist in other oil and gas bearing formations, including shale, in the United States.

We had hoped that our investigation in Sweden would bring forth a means whereby the Ljungstrom In-Situ Method could be used commercially and yield economic results. The closest spacing which we can reasonably consider for use between wells is 104 feet. The Third Bradford Sand formation is 7 to 100 feet in vertical thickness and is found at elevations 1,100 feet to 2,100 feet beneath the sur-face of the ground, or at an average of 1,550 feet. Labor costs in the Bradford area are much higher than similar costs in Sweden. Electric energy cannot be purchased locally for much less than $.01 per KWH under any circumstance.

A copy of the tariff issued by the Public Service Commission of Pennsylvania to Pennsylvania Electric Company, holders of the franchise for distribution and sale of electric energy in the Brad-ford area is herewith enclosed under caption "Electric Energy Tar-iff".

In your booklet entitled "Svenska Skifferolje A.B., Orebro, Sweden", published by Ludvig Larsson Boktryckeri in 1948, at page 10,

appears the following memorandum:

"The electrothermic method is based upon the availability of sufficient quantities of comparatively cheap electric power".

At the present time we are being paid at the rate of $4.10 per barrel (42 gallons) for crude oil, which price is higher than generally may be expected. A schedule entitled "Bradford Oil Field-Annual Average Crude Oil Price" is herewith enclosed for the purpose of showing the price paid for crude oil during the past 30 years. You will note that the average price for the 30 year period is $3.14, for the 20 year period, $2.88, and for the past 10 years, $3.44 per barrel.

A hypothetical test employing the Ljungstrom In-Situ Method upon property in the Bradford Oil Field has been projected for the purpose of establishing economics effecting the same, under the following assumptions:

A. PATTERN

1. Pattern - Hexagonal 7-spot;
2. Spacing - 104' heat to heat or heat to producer;
3. Total area to be heated and produced at the same time - 40 acres;
4. Total number of heat wells - 124;
5. Total number of producers - 62;
6. Depth of wells - 1500';

B. FORMATION AND PAY

1. Vertical formation thickness to be heated - 50';
2. Net pay sand thickness to produce - 40';
3. Average pay sand porosity - 15%;

4. [illegible]

5. Sale price of crude oil recovered -$3.50 per barrel.

C. DEVELOPMENT AND OPERATION

1. Complete redrilling of property using present day costs;

2. Heat wells to be cored but not shot;

3. Producing wells to be shot and equipped with present day pumping units;

D. HEATING DATA

1. Formation temperature now 68°F.

2. Formation temperature to be increased approximately 70°F. to 140°F.

3. Heating element 50' long;

4. Demand per heating element - 18 KW.

E. ELECTRICAL DATA

1. Cost of electrical energy under rate #41 of Pennsylvania Electric Company;
(Franchised distributor of electrical energ

NOTE: Copy of rate tariff as filed with Public [illegible] Commission of Pennsylvania, included here[illegible]

2. Average cost of electricity during life of [illegible] at Bradford, Pennsylvania, rates $.0098 per [illegible]

3. Total demand for 124 heat wells - 2,235 KW.

4. Total average energy per month - 1,610,000 KWH.

5. Electric energy required, allowing 20% heat loss, 1,900,000 KWH per acre or 76,000,000 KWH for 40 acres.

6. Formation temperature increase to 140°F.

7. Electric energy cost - $18,850.00 per acre, or $6,080.00 per heat well.

SUMMARY OF TOTAL COSTS

ESTIMATED INVESTMENT COSTS - PER ACRE

Heat and producing wells, drilled and equipped,

electric lines and equipment, oil storage and run tanks and other miscellaneous costs per acre 29,080.

ESTIMATED OPERATING COSTS - PER ACRE

Maintenance, replacement and miscellaneous operating costs including electricity 28,120.

Total Investment and Operating Costs per acre 57,200.

CONSIDERATION OF ECONOMICS

Assuming there is no royalty to pay, the total recovery required to break even only, would be 1[illegible],500 barrels per acre, or 4[illegible] barrels per acre foot of net pay. This means that to break even the oil saturation in the pay must be reduced down to a residual saturation of 14.9%. It is deemed impossible to reduce the residual saturation to 14.9% by only raising the formation temperature 70°F. (up to 140°F.).

The foregoing calculation was based upon the development and operation of a so-called virgin or previously undeveloped oil producing property in the Bradford Oil Field, McKean County, Pennsylvania, i.e., before the property had been subjected to any type of water flooding or secondary method of development.

The problem in the Bradford Oil Field is to recover oil from so-called depleted oil sands where the residual oil saturation is found to be 36% or less at the present time. The oil bearing formation in the majority of these properties contains a large volume of water which must be moved in order that the oil may be recovered, which condition causes additional operating problems and expense.

Electric energy used at Kvarntorp with shale is 1,017 KWH per barrel of crude oil. At the Bradford rate of $.01 per KWH, electric energy alone would cost $10.17 per barrel of crude produced.

Accordingly, if 16,500 barrels of oil must be recovered (at $3.50 per barrel) in order to break even upon the development and operation of a property, the project is uneconomical to such a serious degree that no attempt should be made to operate a field test or to otherwise employ the use of the Ljungstrom In-Situ Method in the Bradford Oil Field at the present time or in the forseeable future. A drastic reduction in the cost of electric energy could alter this decision materially, however, such a reduction does not appear possible for some time to come.

In view of the foregoing information, and as a result of our investigation, the group of interested parties from Bradford, Pennsylvania, who were joined together for the purpose of investigating the feasibility for use of the Ljungstom In-Situ Method, have requested that I inform you of their decision to dispense with further interest [illegible] method for use in the Bradford Oil Field and other oil and gas bearing formations, including shale, in the United States and Canada. Their decision has been predicated upon the exceedingly <u>high cost for electric energy</u> in the Bradford area, and further upon the high costs applicable to the drilling and equipping of wells locally.

We, of the Bradford group, extend our most sincere thanks and compliments to the very able executive officers and technical experts of Sevenska Skifferolje A.B.. They performed their duties perfectly and were most generous and genial in their effort to afford us knowledge concerning your operation. It would indeed be difficult to name your most able representative, as their individual and collective services were exceedingly well performed.

Please extend our sincere thanks also to Gunnar W. Anderson and Haldor Nordgaard, for the excellent services rendered by them in attempting to procure a satisfactory agreement in behalf of Svenska Skifferolje A.B. and Svenska Entreprenad A.B., with the Bradford group.

In appreciation for all you have done in our behalf, may I suggest that you grant us the privilege to reciprocate in the event we can ever be of service to you.

Respectfully submitted,

Victor H. Samuelson

Victor H. Samuelson

BRADFORD OIL FIELD

ANNUAL CRUDE OIL PRODUCTION

YEAR	BARRELS	YEAR	BARRELS
1871	1,000	1910	2,128,000
1872	2,000	1911	2,152,000
1873	2,000	1912	[illegible],17[illegible],[illegible]00
1874	3,000	1913	[illegible],[illegible]04,000
1875	25,000	1914	2,230,000
1876	382,768	1915	2,256,[illegible]
1877	1,468,481	1916	[illegible],2[illegible]2,000
1878	6,208,746	1917	2,308,000
1879	13,914,509	1918	[illegible],334,[illegible]
1880	22,212,000	1919	[illegible],360,[illegible]
1881	22,945,069	1920	[illegible],386,000
1882	17,959,000	1921	2,415,[illegible]
1883	13,294,886	1922	[illegible],577,726
1884	11,883,000	1923	2,602,777
1885	10,564,298	1924	2,480,540
1886	8,752,797	1925	2,747,620
1887	7,520,979	1926	4,725,252
1888	5,305,062	1927	5,793,707
1889	5,765,053	1928	6,361,703
1890	5,[illegible],735	1929	8,137,125
1891	5,[illegible],413	1930	9,284,230
1892	4,[illegible],061	1931	8,812,133
1893	3,502,136	1932	9,964,235
1894	3,359,835	1933	10,125,458
1895	3,[illegible],808	1934	11,980,248
1896	3,[illegible]4,771	1935	13,183,322
1897	3,[illegible]4,230	1936	14,569,740
1898	3,[illegible],299	1937	16,738,688
1899	3,206,845	1938	15,088,663
1900	3,022,493	1939	14,594,612
1901	2,767,603	1940	14,295,014
1902	2,508,981	1941	13,997,753
1903	2,32[illegible],413	1942	15,532,472
1904	2,167,883	1943	13,684,136
1905	2,11[illegible],225	1944	12,162,521
1906	2,[illegible]22,000	1945	10,792,995
1907	2,048,000	1946	11,756,513
1908	2,074,000	1947	11,512,061
1909	2,1[illegible],000	1948	11,173,528
–	–	1949	9,783,553
TOTAL BARRELS OF OIL PRODUCED 1871–1949			523,852,446

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BRADFORD OIL FIELD

ANNUAL AVERAGE CRUDE OIL PRICE

YEAR	PRICE	PRICE	PRICE
1920	$5.867		
1921	3.328		
1922	3.175		
1923	3.328		
1924	3.695		
1925	3.762		
1926	3.765		
1927	3.156		
1928	3.360		
1929	3.947		
1930	2.596	$2.596	
1931	2.022	2.022	
1932	1.881	1.881	
1933	1.860	1.860	
1934	2.460	2.460	
1935	2.176	2.176	
1936	2.570	2.570	
1937	2.620	2.620	
1938	1.898	1.898	
1939	2.059	2.059	
1940	2.287	2.287	$2.287
1941	2.565	2.565	2.565
1942	2.942	2.942	2.942
1943	3.000	3.000	3.000
1944	3.312	3.312	3.312
1945	3.750	3.750	3.750
1946	3.825	3.825	3.825
1947	4.210	4.210	4.210
1948	4.971	4.971	4.971
1949	3.561	3.561	3.561
TOTAL NO. YEARS	30	20	10
AVERAGE PRICE	$3.14	$2.83	$3.44

NOTE: AVERAGE FOR 3 PERIODS $3.14

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Bradford - projektet.

(Slutrapport)

Vid utvinning av olja ur de oljeförande bergarterna i U.S.A. och annorstädes är utbytet i regel lågt. Under utvinningens första stadium, då oljan med självtryck eller med hjälp av pumpar transporteras upp till markytan, erhåller man i runt tal en tredjedel av hela den tillgängliga oljekvantiteten.

Man började därför ganska snart komplettera denna utvinningsmetod med s.k. secondary recovery, innebärande en utspolning av i berget kvarvarande olja med vatten eller ibland med gas(naturgas). Ung. ytterligare en tredjedel av den totala oljemängden kan man på detta sätt få upp, medan alltså den sista tredjedelen kvarstannar i berget.

Efterhand som de rikaste källorna tappats och efterfrågan på olja stigit har man börjat intressera sig för effektivare metoder för oljans utvinning. Ett uppslag till förbättring av "secondary recovery" har lämnats av dr. Ljungström, enligt vilket oljesanden skulle uppvärmas in situ på elektrotermisk väg. Genom att oljans viskositet och ytspänning därvid sänkas, kan man vänta sig, att den lättare skall rinna fram till borrhålen.

Vid bedömandet av detta förslag måste hänsyn tagas till de olika faktorer, som inverka på dess genomförbarhet, nämligen geologisk- topografiska, ekonomiska och tekniska faktorer, Samtliga dessa ha blivit föremål för särskilda utredningar.

De naturliga förutsättningarna, dvs. belägenheten av för metoden lämpliga förekomster av oljesand i U.S.A. har undersökts och rapporterats av civiling. O. Ljungström (Bradfordrapport 1 - 2). Beträffande oljesandsförekomster i Canada har en (visserligen ofullständig) litteratursammanställning gjorts av undertecknad (Rapport OS-1.)

Metodens ekonomiska förutsättningar har utretts med något olika utgångspunkter, dels av civiling. O. Ljungström (Bradfordrapport 2 och 3) dels av undertecknad (Rapport OS-2).

Vad slutligen de tekniska möjligheterna beträffar, har hittills endast vissa laboratorieundersökningar kunnat göras, vilkas resultat redovisas i rapport OS-3. De resultat, som erhöllos föranledde även en teoretisk utredning om strömningsförhållandena i porösa kroppar (Rapport OS-4).

Ehuru naturligtvis vissa slutsatser kunna dragas ur de erhållna resultaten är det dock fullt klart, att dessa utredningar måste kompletteras med fältförsök i ej alltför liten skala. Man kan nämligen ej med provstycken om några cm^3:s volym erhålla en tillförlitlig bild av förhållandena i berg med en volym av flera miljoner m^3.

För överskådlighets skull ges här ett mycket kortfattat sammandrag av de olika rapporternas innehåll.

Naturliga förutsättningar:

En typisk och ur flera avseenden lämplig oljesandförekomst i U.S.A. är Bradford i Pennsylvanien. Sanden har en mäktighet å djuplad av 10-20 meter och en kvarvarande oljehalt av cirka 4 volyms-%. Den ligger dock på ett stort djup, 400-500 meter.

Bland Canadas enorma tillgångar av oljesand synes förekomsten i Athabaska i norra Alberta vara en av de bäst belägna. Sanden har här en mäktighet av 30-60 meter och en oljehalt av 0-25 vikts-% (ingen olja har hittills uttagits). Djupet varierar också här starkt, men stora delar av Athabaska-sanden gå ända upp i dagen.

Ekonomiska förutsättningar:

I fråga om Bradford tycks de av det stora djupet betingade höga borrkostnaderna bli den avgörande utgiftsposten. Detta medför, att produktionskostnaderna pr utvunnen barrel olja bli relativt höga. I O. Ljungströms rapport 3 har erhållits en beräknad produktionskostnad av $ 4,80 pr barrel, i undertecknads rapport OS-2 en kostnad av $ 4,2 + 5,2 pr barrel. Marknadspriset i U.S.A. är enligt uppgift $ 5:- pr barrel.

Tekniska Förutsättningar:

Enligt den vedertagna Darcy's lag, skulle flödet genom oljesanden vara omvänt proportionellt mot vätskans viskositet och en temperaturhöjning skulle alltså öka flödet i samma takt som viskositeten sjunker. Inga experimentella bevis härför har rapporterats i facklitteraturen. Försöken vid vårt laboratorium ha nu visat, att flödet visserligen stiger vid en temperaturhöjning, men ej på långt när så mycket som motsvarar viskositetsändringen. Såvitt med de relativt primitiva anordningar, som stått till buds, kunnat konstateras, gäller alltså Darcy's lag icke. Samma resultat har även erhållits i den nämnda teoretiska behandlingen av problemet.

Sammanfattning och förslag:

Så långt man kan bedöma av här föreliggande utredningar äro förutsättningarna i Bradford ej tillräckligt gynnsamma för den elektrotermiska metoden. Med hänsyn till den stora betydelse metoden skulle kunna få i dagens oljesituation vore det emellertid synnerligen önskvärt med fältförsök i mindre skala. Dessa skulle emellertid förläggas till en plats med oljesand på relativt ringa djup för att försökskostnaderna ej skulle

bli för höga. En sådan plats bör kunna uppletas i samarbete med de intresserade kontaktmän i U.S.A., som redan ha intresse för saken.

Vidare synes det vara lämpligt, att under tiden närmare undersöka Canadas oljesandsförekomster. Enligt vederhäftiga källor (citerade av Max W. Ball i en artikel 1941) skulle Canada ha oljetillgångar i skiffer och oljesand på 100 — 250 . 10^9 barrels, dvs. betydøligt mer än hela den övriga världens sammanlagda oljetillgångar. Exploateringen av dessa förekomster är emellertid föga utvecklad. Ball uppger, att med dittillsvarande metoder (år 1941) endast några promille av hela oljemängden kunde utvinnas ekonomiskt. Måhända vore därför Canada också den gynnsammaste platsen för det fältförsök, som ovan föreslagits.

Norrtorp den 24.11.48.

Gösta Salomonsson

Bilagor: rapport OS-1,-2,-3,-4.

Oljesandförekomster i Canada.

Uppgifterna i facklitteraturen betr. Canadas oljesandförekomster äro ej på långt när så rikliga som om U.S.A:s oljesand. Detta är emellertid ett tecken, ej på förekomsternas ringa omfattning, utan snarare på att deras tekniska utnyttjande ännu knappast har lämnat experimentstadiet.

Med tanke på ev. möjligheter att i Canada tillämpa den s.k. Ljungströmsmetoden har nedan gjorts en kortfattad litteratursammanställning av de uppgifter som varit åtkomliga. Rapporten är avsedd att ge en uppfattning om förekomsternas belägenhet, geologi, omfattning och art samt om den hittillsvarande bearbetningen. Den bygger i huvudsak på Max. W. Balls utförliga artikel i Canadian Mining and Metallurgical Bulletin Febr. 1941 (1).

Oljesandens läge.

Canadas oljesandförekomster ligga i norra Alberta i Athabaska-området (fig. 1.) Området utgöres av en högslätt av prärietyp, i vilken Athabaska River och dess biflöder ha skurit ned djupa, trånga dalar, nästan canyons. Oljesanden ligger under en stor del av högslätten och går i dagen i floddalarna. Centrum för de kända förekomsterna ligger

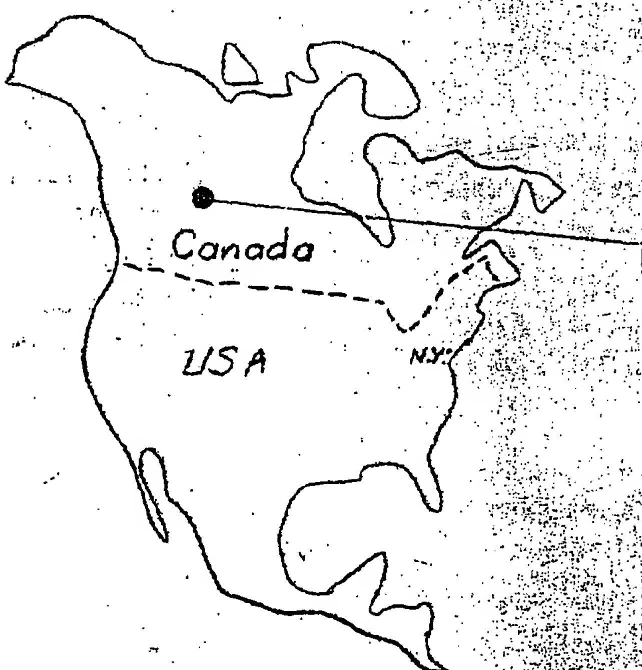

Fig. 1

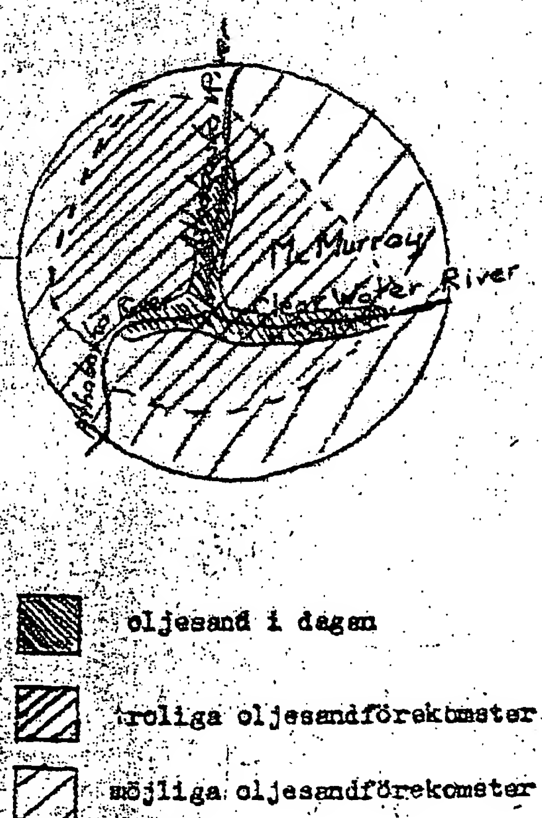

Fig. 2.

i sammanflödet mellan Athabaska River och Clearwater River (fig 2.). Efter fortet Mc Murray benämndes fyndigheten ofta Mc Murray-formationen.

Kommunikationerna äro goda och bestå i järnvägsförbindelse söderut till staden Edmonton och båtförbindelse norrut nedför Athabaska River. Klimatet tillåter drift av där befintliga anläggningar året runt. Årsmedeltemperaturen är ca. $\pm$ 0°C.

Fyndighetens omfattning.

(Då hittills endast i dagen gående fyndigheter ha varit av aktuellt intresse är kännedomen om underjordsfyndigheter högst ofullständig och inskränker sig ofta till rena uppskattningen).

Oljesandslagret är 100-200 feet djupt och har en säker utsträckning av 10.000 square miles, ev. ända till 30.000 sq.miles. Oljehalten varierar mellan 0 och 25 vikts-% med ett genomsnittsvärde av ca. 17 vikts-% i hittills analyserade prov. En på dessa siffror grundad, mycket försiktig beräkning av totala oljeinnehållet ger siffran 100 - 250 . 10^9 barrels olja. Som en jämförelse kan nämnas, att U.S.A:s oljetillgångar i början av 1940 beräknades till 18,5 . 10^9 barrels och hela den övriga världen till 16,9 . 10^9 barrels.

Geologi.

Oljesanden ligger underst i kritperiodens geologiska lager, närmast över Devon-skiktet. Över oljesanden ligger i flera lager ljusa och mörka skiffrar, sandsten m.m. Där hela lagerserien kvarstår utan att ha blivit avnött genom erosion är djupet till oljesanden ca. 1800 feet, men, som ovan framhållits har erosionen varit kraftig på grund av de översta lagrens relativt mjuka beskaffenhet. Tjockleken av de över oljesanden liggande lagren synes minskas något sydväst ut från Mc Murray. Det under oljesanden liggande Devonlagret utgöres av en hård kompakt kalksten med en anmärkningsvärt jämn, horisontell övre yta.

Sandens egenskaper.

Oljesanden utgöres här av kvartskorn, sammankittade av olja. Någon annan kittsubstans finns ej, varför sanden sönderfaller till ett löst, "sockrigt" material, då oljan borttages. Oljan fyller icke ut porerna, utan omger de enskilda kornen som en film. Förmodligen ligger dock närmast kornen, innanför oljefilmen, en tunn vattenfilm (2, 3).

Oljans egenskaper.

Oljan är av helt annan typ än U.S.A:s petroleum. Den är svart, asfaltliknande och så viskös, att den ej flyter vid rumstemperatur. Färsk (icke oxiderad) olja har en spec.vikt av 1,oo-1,o2 Den är mycket känslig för upphettning, varigenom den förändras och blir mera lättflytande. Genom termisk vätskefas- krackning kan man få upp till 40 % bensin, utan att därför förlusterna i form av koks och gas bli högre än ca. 40 %. Bensinen är lättraffinerad och har ett ovanligt högt oktantal (77-82) utan särskild behandling eller tillsatser.

Dessa oljans egenskaper anses tyda på att den är ett ursprungligare mineral än petroleum och att den ej genomgått samma naturliga krackningsprocesser som vanlig petroleum.

Utnyttjningsmöjligheter.

Ball diskuterar de olika möjligheter, som kunna tänkas för utvinning av oljan och kommer till följande slutsatser:

1) Utvinning av oljan måste ske genom brytning av sanden. (Pumpning, förträngning med vatten och dylika metoder äro oanvändbara på grund av oljans tjockflutenhet.)

2) Brytningen kan blott ske, där sanden går i dagen. Sanden och överliggande bergarter äro för lösa för att man skulle kunna öppna schakt utan ett dyrbart stämplingsarbete. Ej heller brytning i horisontella tunnlar är möjligt. Ej ens alla förekomster som "gå i dagen" i floddalarna kunna brytas. På många ställen är sanden nämligen täckt av ett alltför tjockt lager "overburden" (grus, sand och lera) som skulle bli alltför dyrt att avrymma. Avrymningskostnaderna sätta en övre ekonomisk gräns vid en "overburden" av en cu.yard pr ton bruten sand. Därtill kommer att det mycket ofta saknas plats för uppläggning av de avrymda massorna och den bearbetade sanden. Slutligen finns på många ställen i floddalarna ingen plats, där fabriksanläggningarna kunna byggas. Av dessa orsaker ha de mest markerade oljesandförekomsterna längs Athabaska River inget ekonomiskt värde!

Detta gör, enl. Ball att man av Canadas stora oljetillgångar med dittills (1941) kända metoder ej kan tänka sig att utnyttja mer än högst någon promille.

3) Torrdestillation av den brutna sanden skulle bli för dyrbar och samtidigt ej tillräckligt skonsam för den temperaturkänsliga oljan.

4) Extraktion med lösningsmedel skulle bli alltför dyr på grund av svårigheterna att återvinna lösningsmedlet ur sanden.

5) Den enda hittills framkomna användbara metoden består i omröring av sanden i hett vatten. Oljan [illegible] sanden, men flyter [illegible]

grund av sin höga specifika vikt. Detta åstadkommes genom flotering med luft.

Försöksanläggning.

Efter många års prövande av olika metoder i liten skala startades 1930 Abasands Oils Limited, som utarbetat den ovannämnda varm-vatten-metoden och överfört den i halvstor skala. Anläggningen, som är detaljerat beskriver i Balls artikel (1) är avsedd för en kapacitet av 400 ton sand/dygn, motsvarande 350 barrels olja/dygn (=55 m^3/dygn).

Av intresse är att notera, att anläggningen skall producera sitt eget behov av elkraft med en kraftcentral, eldad med krackningsgaser och koks från raffinaderiet.

Anläggningen började byggas 1937, men kunde av olika anledninger ej köras igång förrän 1942. Clark(3) anger emellertid i juni 1944, att anläggningen fortfarande ej fungerar tillfredsställande (beroende på principiella svagheter i metoden) och måste omkonstrueras.

Samma firma har planerat en anläggning i större skala för en produktion av 10.000 barrels/dygn (=ca. 1600 m^3/dygn). Följande beräknade anläggningskostnader kunna vara av intresse:

Produktionsanläggningen	$	4.500.000
Rörledning till Edmonton (300 miles)	"	350.000
Raffinaderi i Edmonton	"	3.150.000
Totala anläggningskostnader	$	8.000.000

Litteratur:

(1) Max. W. Ball: Development of the Athabaska Oil Sands. Canadian Mining and Metallurgival Bulletin (febr. 1941) nr.346: 58-91.

(2) Max. W. Ball: Athabaska Oil Sands: Apparent Example of Local Origin of Oil. Bull. Am. Assoc. Petroleum Geologists (1935) 19:153-171

(3) K.A. Clark: Hot-water Separation of Alberta Bituminous Sand. Canadian Mining and Metallurgical Bull. (June 1944) nr. 386 257-279.

(4) K.A. Clark: Bituminous Sands of Alberta. Oil Weekly 118 (1945) nr. 46-51.

Kommentar till rapporten.

Att döma av de uppgifter, som stått till buds i facklitteraturen har alltså Canada stora förekomster av högvärdig oljesand, men saknar fortfarande

användbara utvinningsmetoder. På grund av oljans egenskaper kunna de i U.S.A. tillämpade metoderna ej överflyttas till Canada. Förutsättningarna för den elektrotermiska metoden synes vara förhanden. En svårighet därvid är, att tillgången på utbyggd elkraft i d aktuella områdena torde vara fullständigt obefintlig. Denna fråga bör dock kunna lö as med hjälp av den goda tillgången på vattenkraft eller med ångkraft ur kräckgaserna från raffinaderiet (vilkan gaser här i ödemarken ej kunna få någon annan användning).

Å andra sidan är det många faktorer, som direkt peka på en in-situ-metod som enda framkomliga vägen.

Av de citerade artiklarna har man också kunnat utläsa, att de kanadensiska myndigheterna hysa det allra största intresse för oljesandens utnyttjande.

Norrtorp den 30.11. 1948.

Gösta Salomonsson